MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

CONTAINING

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REPORTS OF THE PROCEEDINGS

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Dr. J. L. E. DREYER, PRESIDENT, in the Chair.

Albert Clapham, 15 Lonsdale Road, Blackpool;
Frederick H. Clark, c/o Mineral Separation Ltd., 62 London Wall, London, E.C. 2;
Rev. J. Silas Evans, B.A., The Vicarage, Llanrhaiadr, Oswestry;
William David Evans, M.A., 68 Argyle Road, West Ealing, London, W. 13;
Stanislas Kalinowski, Director of the Magnetic Observatory of Swider, rue Gorna 10, Warsaw, Poland;
Philip Sidney Langton, F.R.Met.Soc., Assistant in the Meteorological Service of Canada, 1016 Verrinder Avenue, Victoria, B.C., Canada;
Robert Peebles, 12 Wood Street, London, E.C. 2;
John William Perry, The Research Laboratory, Adam Hilger Ltd., and 14 Hilldrop Road, London, N. 7; and
Archibald C. T. Stevens, c/o Messrs. Wilson & Sons Ltd., 69 Bishopsgate, London, E.C. 2, and Alma House, Freshwater, Isle of Wight,

were balloted for and duly elected Fellows of the Society.

Shin Hirayama, Azabu Observatory, Tokyo, Japan;
J. Fr. Schroeter, Director of the Christiania Observatory, Norway; and
H. von Zeipel, The Observatory, Upsala, Sweden,

were balloted for and duly elected Associates of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Gerald Victor Adendorff, B.Sc., Hilliard's Chambers, Church Square, Cape Town, South Africa (proposed by R. T. A. Innes);

Benjamin Davies Evans, First Assistant, Royal Observatory, Hong Kong (proposed by J. E. Evans);

Francis Charles Seymour Haden, P.O.B. 4402, Johannesburg, South Africa (proposed by R. T. A. Innes);

Joyce Esther Haden, P.O.B. 4402, Johannesburg, South Africa (proposed by R. T. A. Innes);

Joseph Aldridge Holden, B.A., 38 Earl's Road, Bransty, Whitehaven (proposed by F. J. M. Stratton);

Alfred Jobling, A.I.N.A., M.I.M.E., 25 Blenheim Avenue, Ilford, Essex (proposed by W. A. Parr);

Professor John A. Snyder, Philadelphia Observatory, Broad and Green Streets, Philadelphia, U.S.A. (proposed by L. J. Comrie);

William Albert James Weale, B.A., 1 Dyffryn Road, Dyffryn, Pontypridd (proposed by W. H. Rees);

Dr. Harold Wichello, The Crossways, Lache Lane, Chester (proposed by W. E. Plummer); and

James Young, A.R.C.Sc., B.Sc., (Lond.), Assistant Lecturer in Physics at Birmingham University, 116 Franklin Road, King's Norton, Birmingham (proposed by A. Fowler).

One hundred and eighty-seven presents were announced as having been received since the last meeting, including, amongst others :—

Cape of Good Hope, Royal Observatory: Zone Catalogue of 20,843 Stars between 40° and 52° S. Declination.

——————— Cape Astrographic Zones: Catalogue of Rectangular Co-ordinates, vol. vi., zone − 46°.

Rome, Specola Vaticana: Astrographic Catalogue, vol. vi., zone + 59°.

San Fernando Observatory: Astrographic Catalogue, zone − 3°, 16 charts.

Moscow, Institut Astrophysique de Russie: Publications, vol. ii.

Sydney Observatory: Album of Photographs of the Total Solar Eclipse, 1922 September 21.

Utrecht Observatory: Recherches Astronomiques, vol. ix.

Washington, Bureau of Standards: Scientific Papers, Nos. 319–467.

Washington, National Academy of Sciences: Bulletin, vols. i.–v.

The Systematic Motions of the Faint Stars in Four Photographic Regions. By W. M. Smart, M.A., D.Sc.

(*Communicated by Professor A. S. Eddington, F.R.S.*)

§ 1. The results of the present paper are based on the proper motions of stars in the following four regions:

Number.	Central Star.	R.A. (1900)	Dec.	No. of Stars.
		h m	° ′	
I.	η Cassiopeiæ	0 43·0	+57 17	225
II.	η Geminorum	6 8·8	+22 32	124
III.	Lalande 43492	22 12·3	+12 24	57
IV.	Krüger 60	22 24·5	+57 12	83

The plates of the earlier epoch were obtained in 1903–04 by A. R. Hinks and H. N. Russell while engaged in their parallax programme with the Sheepshanks telescope. The exposures on the earlier plates were from 3 to 5 minutes—sufficient to show measurable images of stars down to photographic magnitude 12 approximately. The later plates with which the parallax plates have been compared were photographed through the glass, and the interval on which the proper motions depend is about 18 or 19 years. The number of comparisons has been 6 or more for the regions considered, 2 or 3 pairs of plates with 2 or more images of each star per plate being measured.

The reduction of the measures to yield proper motions relative to a number of suitably situated comparison stars—from 20 to 40 in number—was effected by the method described in *Monthly Notices*, **81**, 536.

§ 2. The relative proper motions can be exhibited conveniently by plotting, on squared paper, points whose co-ordinates are the components of the relative proper motions. To study the distribution of the absolute motions, it is necessary to derive a new origin referred to which the points on the squared paper represent the individual absolute motions. In §§ 3, 4 below, it is shown how the conversion of relative to absolute motion—or what amounts to the same thing, the appropriate change of origin on the squared paper—can be accomplished.

When the absolute motions of Region I. were examined, it was evident at once that there was a systematic tendency of the stars to move in two directions, later identified as the approximate directions, for this part of the sky, of Drift I. and Drift II. With the only exception of G. C. Comstock, as far as I am aware, whose investigation on star-streaming was based on the proper motions of nearly 500 faint stars, limiting magnitude 13, scattered over the sky (*A.J.*, **28**, 49), investigators on the systematic motions of the stars have confined their attention to the brighter stars for which meridian proper motions are available.* The evidence from Region I.—a little more than a square

* It should be mentioned, however, that the recent investigation of W. J. Luyten (*Lick Observatory Bulletin*, No. 344, Jan. 1923) dealt with 749 stars whose proper motions exceed 50″ per century, a considerable number (178) of these being Boss stars. The faintest magnitude is about 14.

degree in area and containing 225 stars from magnitude 8 to fainter than 12—indicates that star-streaming also occurs among the fainter stars, and that the directions and strengths of the streams are not sensibly the same as for the bright stars.

Three other regions (II.–IV.) have been examined in the same way, and the signs of star-streaming are clearly visible even in Regions III. and IV., which contain a comparatively small number of stars.

§ 3. To convert relative into absolute proper motions, three courses are open:—

(*a*) If there is a sufficient number of stars, in each field, whose absolute proper motions have been determined from meridian observations, the correction to the relative proper motions is easily obtained. The minimum number of stars required for this purpose would be not less than 10 (see Van Rhijn: *Third Report on the Progress of the Plan of Selected Areas*, 1923, p. 27), and it may be recollected that a section of the work prescribed in the "Plan of Selected Areas" is the determination of proper motion from meridian observations of certain representative stars in each area. In the four fields with which this paper deals, the number of stars with well-determined proper motions is totally inadequate to give a sufficiently reliable origin for the absolute motions.

(*b*) The extremely faint stars may be presumed to form a nearly stationary background, and the proper motions relative to these presumably very distant stars would be for practical purposes a satisfactory approximation to the absolute motions. The limiting magnitudes in our four fields, however, are not sufficiently faint to achieve the purpose in view.

(*c*) From the mean parallax π_m of a group of stars of determined magnitude m, the parallactic motion of the group can be found. The mean relative motions of the group can then be compared with the parallactic motion and the origin of absolute motions determined. This method—adopted in the reduction of the four regions—is certainly, at the present time, more satisfactory than the first, in which the systematic errors of the meridian proper motions must introduce considerable uncertainty into the position of the origin of absolute motions, derived in this way. An error of 10 per cent. in π_m for stars of magnitude 9 could lead to a maximum error of about $0''.2$ in the centennial proper motions—a quantity very much smaller than one would expect in the case of (*a*) above.

The mean parallax π_m is a function of the galactic latitude: in this investigation, the values of π_m were taken from *Groningen Publications*, No. 29, Table 26, which gives the mean secular parallax as a function of visual magnitude (Harvard scale) and galactic latitude, the Sun's velocity being taken as 19·5 kilometres per second.

Take the x-axis through the centre of the region, parallel to the equator and in the direction of increasing R.A., and the y-axis along the meridian through the centre towards the north pole. Let λ, χ denote, respectively, the angular distance of the centre of the field from the solar ant-apex and the position angle of the ant-apex at the centre. The values of λ and χ can be conveniently and expeditiously found from the series of charts, recently published by the Society, the con-

struction of which I described in *Monthly Notices*, 83, 465. If, further, P_x, P_y denote the components of parallactic motion per century of a star of magnitude m, then using the value of the Sun's velocity above, we have

$$P_x = 4{\cdot}10\ \pi_m \sin\lambda \sin\chi$$
$$P_y = 4{\cdot}10\ \pi_m \sin\lambda \cos\chi.$$

If M_x, M_y are the components of the mean centennial relative motions of a group of stars of magnitude m, the origin of absolute motions—referred to the origin of relative motions—has co-ordinates $(M_x - P_x)$, $(M_y - P_y)$; or, expressed otherwise, the relative motions are converted into absolute motions by adding to the former the quantities

$$P_x - M_x \text{ and } P_y - M_y.$$

The success of the method depends (i) on having a sufficiently large number of stars of each magnitude group with which to make the comparison, and (ii) on the absence of systematic motions of these stars wholly or in part. If these conditions are approximately satisfied, the random motions will tend to cancel out on the whole and the transference of the origin by this method will be legitimate.

§ 4. In the regions under consideration, the B.D. stars only were treated by the method of the previous paragraph; for these, the visual magnitudes are known, whereas for the remaining stars, the reduction of the photographic magnitudes (even when known) to the visual scale presents a certain amount of difficulty. To reduce the magnitudes of the B.D. stars to the Harvard Scale, on which Kapteyn's tables of mean secular parallaxes depend, the correction "H.S. *minus* B.D.," taken from *Groningen Publications*, No. 30, p. 12, was applied. The table is reproduced below.

TABLE I.

Mag. B.D.	H.S. *minus* B.D.
m m	m
6·5 – 6·9	0·0
7·0 – 8·6	+0·1
8·7 – 9·2	+0·2

The number of B.D. stars available for comparison in each of the four regions is shown in Table II.

TABLE II.

Region.	No. of B.D. Stars.
I.	34
II.	51
III.	28
IV.	49

Actually, the B.D. stars were arranged according to magnitude in three or four groups, and the procedure outlined in § 3 applied for each group separately. This method has the advantage of showing or indicating,

however roughly, whether the brighter B.D. stars have systematic motions relative to the fainter.

The parallactic motions P_x, P_y are expressed by the equations in § 3 in seconds of arc per century. By multiplying by a factor F depending on the time-interval T between the comparison plates and on the scale value of the measuring machine (1 scale unit = 0″·01758) P_x, P_y can then be made to represent the components of the parallactic motion during the interval between the comparison plates, expressed in the scale units. Clearly,

$$F = \frac{T}{1{\cdot}758}.$$

For the purposes of this paper, it is more convenient to keep the proper motions of all the stars expressed in scale units for the particular interval T concerned.

§ 5. The procedure in the case of Region IV. is shown. For this region we have the following:—

Galactic Latitude = 0°
λ = 130°·5
χ = 92°
T = 18·8 years
F = 10·7
In scale units, for 18·8 years, $P_x = +312 \times 10{\cdot}7\pi_m$
,, ,, ,, $P_y = -11 \times 10{\cdot}7\pi_m$.

If also M_x, M_y are now the components of the measured relative motions (in scale units) during the interval T, the algebraic sum of M_x and M_y can be obtained immediately from the measures for all the stars in each magnitude group.

In Table III., the number N of stars in each of four magnitude groups, and the values of P_x, P_y are given.

TABLE III. (*Region IV.*)

Mean Mag. B.D.	Mean Mag. H.S.	No. of Stars N.	π_m.	P_x.	P_y.
			″		
7·4	7·5	3	0·0070	+23·3	−0·7
8·5	8·6	8	0·0049	+15·9	−0·5
9·0	9·2	13	0·0041	+13·6	−0·4
9·4	9·6	25	0·0037	+12·2	−0·4

In Table IV., the third column gives ΣM_x for each of the magnitude groups; the fourth column gives $\Sigma M_x - NP_x$ from columns 3 and 2. If ξ is the x-component of the displacement of the origin of relative motions to the origin of absolute motions, $\xi = -565/49$. The fifth column gives $N\xi$ for each of the magnitude groups. The sixth column gives the residuals for each group, and the last column gives the average residual for each star in the groups.

TABLE IV. (*Region IV.* : x-*Components.*)

N.	NP_x.	ΣM_x.	$(\Sigma M_x - NP_x)$. Observed.	$(\Sigma M_x - NP_x)$. Calculated.	Group Residual.	Average Residual for each Star in Group.
3	+ 70	+10	− 60	− 35	−25	−8
8	+127	−16	−143	− 92	−51	−6
13	+177	+89	− 88	−150	+62	+5
25	+305	+31	−274	−288	+14	+0·5
49	...	...	−565	−565	0	...

Table V. gives the corresponding details for the y-components.

TABLE V. (*Region IV.* : y-*Components.*)

N.	NP_y.	ΣM_y.	$(\Sigma M_y - NP_y)$. Observed.	$(\Sigma M_y - NP_y)$. Calculated.	Group Residual.	Average Residual for each Star in Group.
3	− 2	+10	+12	+ 6	+6	+2
8	− 4	+ 8	+12	+15	−3	0
13	− 5	+19	+24	+25	−1	0
25	−10	+35	+45	+47	−2	0
49	...	...	+93	+93	0	...

The origin of absolute motions has, then, co-ordinates (ξ, η) referred to the origin of relative motions, where

$$\xi = -565/49 \text{ and } \eta = +93/49$$

or

$$\xi = -11{\cdot}5, \qquad \eta = +2.$$

Stated differently, if we add +11·5 and −2 to the measures of the respective components of relative proper motion, we obtain the absolute proper motions (expressed in scale units), for the interval T, of every star in the region.

In compiling the above tables, no B.D. star was rejected because of comparatively large proper motion. From Table V. it is seen that the correction $(\Sigma M_y - NP_y)$ is as satisfactorily consistent for each group as could be reasonably anticipated. The value of η is naturally small as the direction of the ant-apex is nearly parallel to the equator. For the x-components, however, Table IV. would appear to indicate an excess of negative motions in the group of stars of magnitude 8·6 and an excess of positive motions in the group of stars of magnitude 9·2. The character of the residuals in the last column of Table IV. might be interpreted in terms of magnitude equation or of driving error or a residual systematic motion of the brighter stars not shared by the fainter; on the other hand, the number of stars used for the comparison is not as large as one would wish, and the small inconsistencies of Table IV. may be purely accidental. I have thought it advisable to point out, by means of a

single example, viz. Region IV., the nature of the irregularities likely to be encountered in dealing with a problem of this kind.

§ 6. Having now obtained the origin of absolute motions, one can now proceed to study the distribution of the absolute proper motions as represented by the dots on the squared paper. If there is no systematic motion of the stars, the dots should be arranged more or less symmetrically about the origin. A glance at the squared paper is generally quite sufficient to show whether there is a marked tendency for the stars to move in one or more directions or no. For each of the four regions, counts were made of stars having proper motions lying within each of 36 sectors of 10°. Using the number of stars in a sector as the radius vector, one can draw, for each of the regions, polar curves such as are to be found in Professor Eddington's *Stellar Movements and the Structure of the Universe.* Actually, the curves shown below were smoothed out by taking as the radius vector, for a position angle θ, the number of stars in the 30° sectors, $\theta - 15°$ to $\theta + 15°$, the values of θ progressing by 10°.

Table VI. gives the number of stars in the 10° sectors, $\theta - 5°$ to $\theta + 5°$, for each of the four regions. From these counts, the value of r—the radius vector corresponding to each of the 30° sectors—can be readily found. The curves $r = f(\theta)$ are shown below for each region :—

TABLE VI.

Distribution of Proper Motions in Direction.

θ	Region.				θ	Region.			
	I.	II.	III.	IV.		I.	II.	III.	IV.
0°	2	1	0	0	180°	9	13	4	7
10	2	0	0	1	190	15	12	2	3
20	1	0	0	0	200	10	16	0	2
30	1	0	0	3	210	10	12	1	2
40	4	0	0	1	220	8	5	0	1
50	1	0	1	3	230	10	4	1	3
60	3	1	3	7	240	4	2	4	2
70	7	2	1	6	250	6	1	0	1
80	4	3	6	10	260	2	2	0	1
90	10	3	4	6	270	2	0	0	1
100	7	2	5	6	280	2	0	0	0
110	17	1	2	1	290	1	0	0	0
120	14	6	2	2	300	2	1	1	0
130	19	8	1	4	310	2	1	0	0
140	19	3	2	2	320	0	0	2	0
150	14	5	7	1	330	1	0	2	0
160	13	11	1	4	340	1	0	1	0
170	2	9	4	2	350	0	0	0	1

In each of the diagrams the directions of Drift I., Drift II., and the ant-apex of the solar motion are shown. In calculating the former, the following positions of the drift apices were used:

Drift I. : R.A. 90°, Dec. −14°
Drift II. : R.A. 288°, Dec. −64°

λ, λ_I, λ_{II} will be used to denote the angular distances of the centre of a region from the solar ant-apex and the apices of Drift I. and Drift II. respectively.

It is also desirable to have a sufficiently precise idea of the limiting magnitudes of the stars in each region. The magnitudes have not been individually determined from the plates, and it is not always possible to obtain these unless the field lies within an astrographic zone for which magnitudes have been published. It is, however, possible to derive the limiting magnitude of the stars in the regions, with a fair approach to accuracy, from Kapteyn's estimates of the total average number of stars, per square degree, down to a magnitude *m* (*Groningen Publications*, No. 27, p. 59). These limiting magnitudes have been derived for each region, and are given in the next four paragraphs.

§ 7. *Region I.* (η Cassiopeiæ).

For this region we have:—

Galactic Latitude	= − 4°
Position Angle of Ant-apex	= 118°
,, ,, apex of Drift I.	= 108°
,, ,, ,, Drift II.	= 220°
λ, λ_I, λ_{II}	= 112°, 96°, 136° respectively.
Limiting Magnitude (H.S.)	= $12^m{\cdot}7$.

Fig. 1 shows clearly the systematic motions of the 225 stars of the region. Fig. 1A below is reproduced from Professor Eddington's *Stellar Movements*; it is the second figure on p. 95. It exhibits the systematic motions of Boss stars in a large region whose centre is at R.A. $0^h\ 0^m$, Dec. +50°. The centre of my Region I. is at R.A. $0^h\ 43^m$, Dec. +57°. The two centres are sufficiently close to permit of a rough comparison of the systematic motions of the fainter stars of fig. 1 with those of the much brighter Boss stars of fig. 1A. The general features of the distribution of the motions have much in common; one noticeable difference, however, is that Drift II. is much stronger, relatively to Drift I., in fig. 1 than in fig. 1A.

§ 8. *Region II.* (η Geminorum).

For this region we have:—

Galactic Latitude	= + 2°
Position Angle of Ant-apex	= 182°
,, ,, apex of Drift I.	= 183°·5
,, ,, ,, Drift II.	= 191°
λ, λ_I, λ_{II}	= 57°, 36½°, 137° respectively.
Limiting Magnitude (H.S.)	= $12^m{\cdot}1$.

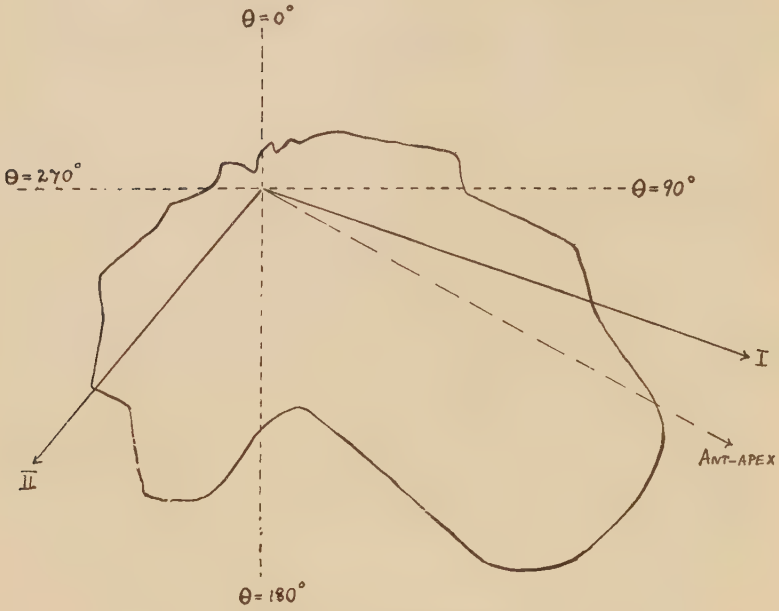

FIG. 1.—(*η Cassiopeiæ*).

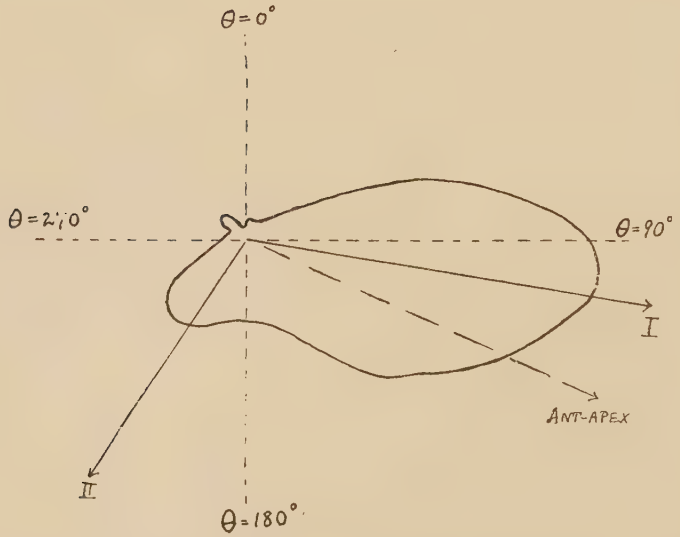

FIG. 1A.—(Eddington, *Stellar Movements*, p. 95).

Fig. 2 shows the distribution of motions for Region II. The directions of the ant-apex and of the apices of Drift I. and Drift II. are nearly the same, and the maximum frequency, as one would expect, is approximately in the direction $\theta = 190°$. The curve is interesting, not because it fails (as it is bound to fail) to resolve the two drifts,

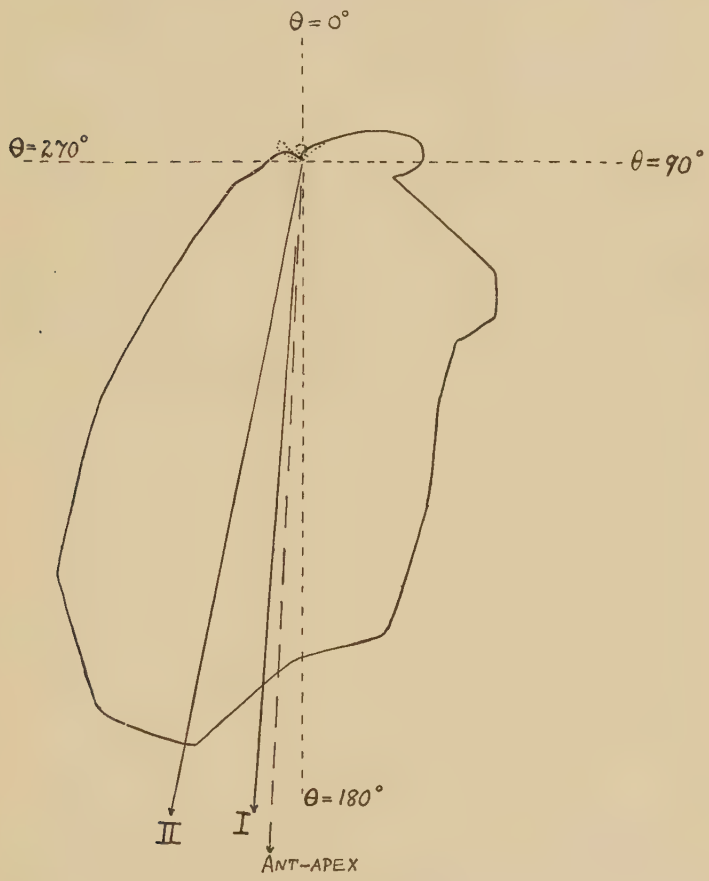

Fig. 2.—(η *Geminorum*).

but rather because it shows no systematic motions other than in the direction $\theta = 190°$. The detail (shown dotted) in the north-west quadrant has no significance—it is the consequence of the too minute division of sectors in a part of the figure with a scanty number of stars. The full curve in this quadrant is the result of smoothing the dotted curve.

§ 9. *Region III.* (Lalande 43492).
For this region we have :—

Galactic Latitude	$= -38^\circ$
Position Angle of Ant-apex	$= 122\frac{1}{2}^\circ$
,, ,, apex of Drift I.	$= 102^\circ$
,, ,, ,, Drift II.	$= 200^\circ$
λ, λ_I, λ_{II}	$= 119^\circ, 119^\circ, 84^\circ$ respectively.
Limiting Magnitude (H.S.)	$= 12^m{\cdot}3$.

Fig. 3 shows the distribution of motions for Region III. There are

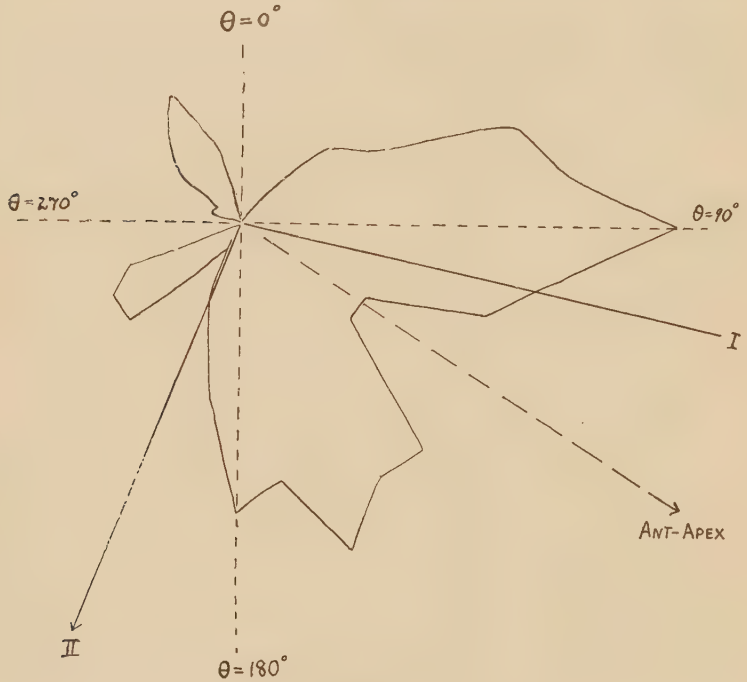

FIG. 3.—(*Lalande* 43492).

only 57 stars, and it is hardly to be expected that the curve will present a faithful account of the phenomena of star-streaming. As it is, there are two directions of maximum frequency, one at $\theta = 90^\circ$, which approximates fairly closely with Drift I., and the other at $\theta = 160^\circ$, the approximation here not being so satisfactory.

In this field there are two stars with meridian proper motions : (i) Lalande 43492, for which the centennial proper motions are : $\mu_\alpha = +5^{s}{\cdot}78$, $\mu_\delta = +10''{\cdot}2$ (*Cincinnati Publications*, No. 19); (ii) B.D. 11°4776 (RüH. 15766), for which $\mu_\alpha = +0^{s}{\cdot}48$, $\mu_\delta = -9''{\cdot}2$ (R. Schorr : *Eigenbewegungs-Lexikon*). Regarding these proper motions as absolute proper motions and comparing them with the measured relative proper motions, we can, in the case of each star, derive the co-ordinates (ξ, η) of the

origin of absolute motions referred to the origin of relative motions. The values of these co-ordinates can be compared with the values derived by considering the parallactic motions of all the B.D. stars in

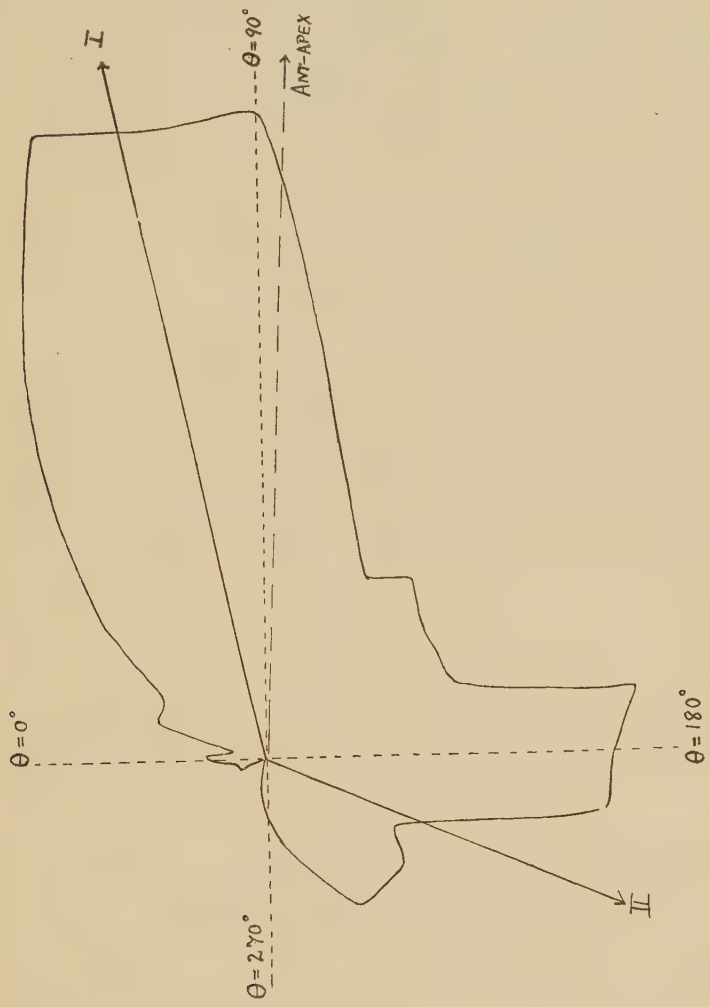

FIG. 4.—(*Kriiger* 60).

the field. Table VII. shows the results of the three comparisons (the units are those of § 4).

TABLE VII.

	ξ.	η.
From Parallactic motions	−11	+12
,, Lalande 43492	+ 3	+11
,, B.D. 11°4776	−27	− 7

The large discordances shown in the last two lines of Table VII. can hardly be attributed to errors in the measures of the images of the stars concerned: it is safer to ignore these meridian proper motions as far as the calculations of (ξ, η) is concerned, and to use the values obtained from the consideration of the parallactic motions alone. The proper motions of the two stars from the Cambridge measures are:—

Lalande 43492; $\mu_\alpha = +5^s\cdot88$: $\mu_\delta = +10''\cdot1$
B.D. $11^\circ4776$; $\mu_\alpha = +0^s\cdot37$: $\mu_\delta = -11''\cdot1$.

§ 10. *Region IV.* (Krüger 60).
For this region we have:—

Galactic Latitude	$= 0^\circ$
Position Angle of Ant-apex	$= 92^\circ$
,, ,, apex of Drift I.	$= 78^\circ$
,, ,, ,, Drift II.	$= 204^\circ$
	$\lambda, \lambda_I, \lambda_{II} = 130\frac{1}{2}^\circ, 115^\circ, 126^\circ$.
Limiting Magnitude (H.S.)	$= 11^m\cdot7$.

Fig. 4 shows the distribution of motions in Region IV. Despite the fact that the total number of stars considered is only 83, the features of the star-streaming are exhibited with surprising clearness and accuracy.

§ 11. *Magnitudes of the Proper Motions.*—Let μ denote the centennial absolute proper motion of a star along the great circle. The numbers of stars between successive limits of μ are obtained from the squared paper diagram. The results are given in Table VIII. for each of the four regions.

TABLE VIII.

μ.	I.	II.	III.	IV.
$0''\cdot0 - 1''\cdot0$	23	30	4	18
$1''\cdot0 - 2''\cdot0$	51	44	21	30
$2''\cdot0 - 3''\cdot0$	74	31	16	16
$3''\cdot0 - 4''\cdot0$	41	10	12	10
$4''\cdot0 - 5''\cdot0$	17	3	1	3
$5''\cdot0 - 6''\cdot0$	6	3	0	0
Over $6''\cdot0$	13	3	3	6

For Region I. the maximum frequency occurs for $\mu = 2''\cdot4$, and for the remaining regions for $\mu = 1''\cdot5$.

Observatory, Cambridge:
1923 *October* 31.

A Troublesome Systematic Error. By Frederick H. Seares, Assoc. R.A.S.

The progression in stellar velocity with absolute magnitude discussed by Eddington and Miss Douglas in the January *Monthly Notices* * touches a matter of wider import than their article suggests. They have shown that "the *accidental* error of the magnitudes produces a *systematic* error in the deduced change of velocity . . ."; but it is of interest to note that the systematic error seems to be inherent in the magnitudes themselves and to arise from the general impossibility of combining *observed* magnitudes into means which are free from such error. The systematic effect originates in the combined influence of accidental error of observation and unequal probability in the true values of the quantity measured. Moreover, what is thus true of magnitudes is also true of any characteristic whose true values are not equally probable and whose observed values are affected by errors of measurement. The systematic error of the mean is often, perhaps usually, negligible; but if the mean error of observation happens to be a considerable percentage of the standard deviation of the measured characteristic, it may be serious. The existence of such an error must have been noted by those engaged in statistical investigations; but it does not seem to be mentioned in the literature, and on that account it may be worth while to point out its origin and behaviour.

The source of the systematic error in tangential velocity is easily located by forming the arithmetical mean of the logarithms of the velocity. In the usual notation, $T = \mu/\pi$ and $M = m + 5 + 5 \log \pi$, whence, for true values,

$$\log T = \log \mu - 0{\cdot}2(M - m) + 1 \quad . \quad . \quad . \quad (1)$$

Let M' be the observed absolute magnitude and T' the corresponding velocity. Since the discussion is concerned with the influence of errors in M', uncertainties in proper motion μ and apparent magnitude m are disregarded. The error in $\log T'$ is, accordingly,

$$\log T - \log T' = -0{\cdot}2(M - M') = -0{\cdot}2\epsilon \quad . \quad . \quad (2)$$

where ϵ is the error of M'. This relation is equivalent to equation (1) by Eddington and Miss Douglas. Applied to a group of magnitudes in the interval M' to $M' + dM'$, it gives the mean

$$\overline{\log T} - \overline{\log T'} = -0{\cdot}2(\bar{M} - \bar{M}') = -0{\cdot}2\bar{\epsilon} \quad . \quad . \quad (3)$$

The error in $\overline{\log T'}$ is therefore one-fifth the error in $\bar{M}'$, with the sign reversed. It makes no difference whether $\overline{\log T'}$ is calculated from the individual velocities or from mean values of $\log \mu$, M', and m by an equation of the form of (1). The error is the same function of $\bar{\epsilon}$ whether $\bar{M}'$ is actually formed or not; and since this error, as shown by Eddington and Miss Douglas, is systematic, $\bar{\epsilon}$ must also be systematic. The error in $\overline{\log T'}$ is thus traced to systematic error in $\bar{M}'$.

* Vol. 83, p. 112.

The point emphasised here, however, is the systematic character of $\bar{\epsilon}$, which is obvious enough from general considerations when once attention is directed to the matter. A formal proof is as follows: Suppose M to follow the Gaussian frequency law

$$F_1(M)dM = \frac{k}{\sqrt{\pi}} e^{-k^2M^2} dM \quad . \quad . \quad . \quad (4)$$

M being counted from the value corresponding to maximum frequency. Further, suppose the errors of observation to be distributed according to

$$F_2(\epsilon)d\epsilon = \frac{h}{\sqrt{\pi}} e^{-h^2\epsilon^2} d\epsilon \quad . \quad . \quad . \quad . \quad (5)$$

Consider those stars in the interval M′ to M′ + dM' whose observed magnitudes have the value M'_1. Since

$$M'_1 = M - \epsilon \quad . \quad . \quad . \quad . \quad . \quad (6)$$

a given M'_1 may result from various combinations of M and ϵ, and the probability that M'_1 is affected by a specified ϵ is equal to the normal probability of that ϵ multiplied by the probability of an M which together with ϵ satisfies (6).

In practice the unit for M and ϵ is the same. The probabilities of values of these quantities within the unit intervals $M \pm 1/2$ and $\epsilon \pm 1/2$ are $F_1(M)$ and $F_2(\epsilon)$ respectively. Hence, the probability of an error in M'_1 within the same unit interval $\epsilon \pm 1/2$ is

$$F_3(\epsilon) = F_1(M)F_2(\epsilon) = F_1(M'_1 + \epsilon)F_2(\epsilon) \quad . \quad . \quad (7)$$

This presupposes M and ϵ to be independent, an assumption which, like those underlying (4) and (5), may or may not be true. For the moment all three assumptions are admitted.

With the aid of the mean value theorem, equation (7) gives at once for the mean of the errors affecting the observed magnitudes having the value M'_1

$$\bar{\epsilon} = \int_{-\infty}^{+\infty} \epsilon F_1(M'_1 + \epsilon)F_2(\epsilon)d\epsilon \div \int_{-\infty}^{+\infty} F_1(M'_1 + \epsilon)F_2(\epsilon)d\epsilon \quad . \quad (8)$$

This expression can be evaluated by the usual methods, but much more directly by noting that the frequency function for the errors affecting the selected group of magnitudes, namely,

$$F_3(\epsilon)d\epsilon = \frac{kh}{\pi} e^{-k^2(M'_1+\epsilon)^2 - h^2\epsilon^2} d\epsilon$$

is Gaussian, and may be written

$$F_3(\epsilon)d\epsilon = Ke^{\gamma\left(\epsilon + \frac{\beta}{2\gamma}\right)^2} d\epsilon$$

where $\beta = -2k^2M'_1$, $\gamma = -(k^2 + h^2)$, and where K is independent of ϵ.

The values of ϵ are therefore distributed about the mean value $-\beta/2\gamma$. Hence,

$$\bar{\epsilon} = -\frac{k^2}{k^2+h^2}\mathrm{M'}_1. \quad . \quad . \quad . \quad . \quad (9)$$

For other groups of stars within the interval M′ to M′ + dM′, each having the observed values M′$_2$, M′$_3$, etc., a similar equation holds. Hence, for *all* the stars within M′ and M′ + dM′

$$\bar{\epsilon} = -\frac{k^2}{k^2+h^2}\overline{\mathrm{M}}' \quad . \quad . \quad . \quad . \quad (10)$$

The modulus k refers to the frequency function of the true absolute magnitudes. If k' be the corresponding quantity for observed values,

$$\frac{1}{k'^2} = \frac{1}{k^2} + \frac{1}{h^2}.$$

Then

$$\bar{\epsilon} = \overline{\mathrm{M}} - \overline{\mathrm{M}}' = -f\overline{\mathrm{M}}' \quad . \quad . \quad . \quad . \quad (11)$$

where

$$f = \frac{k^2}{k^2+h^2} = \frac{k'^2}{h^2} = \frac{\epsilon_0^{\,2}}{\sigma^2} = \frac{r^2}{\mathrm{R}^2}. \quad . \quad . \quad . \quad (12)$$

in which ϵ_0 is the ordinary mean error of observation; σ, the standard deviation of M′; and r and R, the probable error and probable deviation respectively.

The error $\bar{\epsilon}$ in $\overline{\mathrm{M}}'$ is therefore systematic and proportional to $\overline{\mathrm{M}}'$ itself. The factor f is the square of the ratio of the dispersion in the errors of observation to the dispersion in the measured characteristic. M and M′, it must be remembered, are counted from the values of greatest frequency.

The relation between $\overline{\mathrm{M}}$ and $\overline{\mathrm{M}}'$ can also be written

$$\overline{\mathrm{M}} = g\overline{\mathrm{M}}' \quad . \quad . \quad . \quad . \quad . \quad (13)$$

where

$$g = 1 - f = \frac{h^2}{k^2+h^2} = \frac{k'^2}{k^2} \quad . \quad . \quad . \quad (14)$$

Formulæ (10) to (14) are in agreement with the results of Eddington and Miss Douglas. By (3) and (11)

$$\overline{\log \mathrm{T}} - \overline{\log \mathrm{T}'} = 0{\cdot}2f\overline{\mathrm{M}}' \quad . \quad . \quad . \quad . \quad (15)$$

Assume now that the progression in $\overline{\log \mathrm{T}}$ with M′ is linear, and write

$$\overline{\log \mathrm{T}} = a + b\overline{\mathrm{M}} \qquad \overline{\log \mathrm{T}'} = a' + b'\overline{\mathrm{M}}' \quad . \quad . \quad (16)$$

By considering the special case $\overline{\mathrm{M}}' = 0$, we find from (11), (15), and (16), $a' = a$. Then, from (15), (16), and (13),

$$b' = \frac{bh^2 - 0{\cdot}2k^2}{k^2+h^2} \quad . \quad . \quad . \quad . \quad (17)$$

The logarithms are here to the base (10). With allowance for this circumstance, (17) is identical with the corresponding equation given by Eddington and Miss Douglas on page 115 of their paper. The difference for a' and a arises from the fact that they have formed the logarithm of the arithmetical mean velocity, whereas the mean of the logarithms has been used here. Adapted to the latter case, their formulæ also give $a' = a$.

The results expressed by equations (11) to (14) are of general interest in that they apply to any characteristic distributed according to a Gaussian frequency law. As for absolute magnitudes, consider the group of giant stars discussed by Eddington and Miss Douglas. They find $k' = 0{\cdot}817$ and adopt $h = 1{\cdot}59$. Hence, by (11) and (12) the systematic error affecting the mean observed magnitude for a group of these stars within the interval M' to $M' + dM'$ is approximately $-\overline{M}'/4$.

The range for the group of giants is about 7 magnitudes, but it is doubtful if a Gaussian distribution holds for the extremes of luminosity, especially on the brighter side. Hence, for the brightest and faintest members of the group the theoretical expression for the error may not be strictly applicable. For sub-groups nearer the maximum, however, the frequencies are approximately Gaussian; and, as an illustration, for $\overline{M}' = 1$ and 2 magnitudes, the errors should be of the order of 0·25 and 0·5 magnitudes respectively.

A case frequently occurring in practice involves the selections and combination of data from lists of stars which are more or less complete to some limit of apparent magnitude. Suppose, for example, the data to be representative to $m = 6$. The distribution of absolute magnitudes among the stars brighter than this limit is approximately Gaussian, with $k = 0{\cdot}4$.* For $h = 1{\cdot}6$ as before, $f = 0{\cdot}06$. The mode is at $M = -0{\cdot}1$; hence, for stars between $M = +5$ and $+6$, $\bar{\epsilon} = -0{\cdot}3$ magnitude.

The case involving a representative selection of all the stars in a given volume of space is more favourable in that the frequency law for M is then the luminosity function of Kapteyn. The modulus k is small and hence f is small, of the order of 0·03 or 0·04; but the mode is $M = +7{\cdot}7$, and $\overline{M}'$ may be large, 10 magnitudes or more, so that even here $\bar{\epsilon}$ may attain values equivalent to a systematic error of 15 or 20 per cent. in the corresponding mean parallax.

Other instances in which similar systematic errors may be of importance readily suggest themselves; for example, those involving parallaxes or proper motions. In the case of radial velocities, on the other hand, the precision of measurement is relatively high, and serious error is not to be expected. Thus for early type stars the mean velocity without regard to sign is about 10 km./sec. Hence, $k' = 1/10\sqrt{\pi} = 0{\cdot}06$. For a probable error of ± 1 km./sec., f is only 0·01 or 0·02, and the systematic error is for most purposes negligible. For faint dwarf stars observed with very low dispersion, however, we may have a mean radial velocity of, say, 30 km./sec., with a probable error ± 4 km./sec. for a single observation. In that case, $k' = 1/30\sqrt{\pi} = 0{\cdot}02$, $h = 0{\cdot}477/5 = 0{\cdot}10$ and

* See a *Contribution* soon to appear in the *Astrophysical Journal*, entitled "Remarks on the Luminosity Function."

$f = 0{\cdot}04$. For the large velocities found among dwarfs $\bar{\epsilon}$ would be appreciable, but probably not statistically important except in special cases, such as that involving the determination of mean radial velocity as a function of absolute magnitude.

It should be noted that there is always danger of trouble in attempting to determine the relation of absolute magnitude to any other characteristic, x, even when x itself is free from error. The observed data give $x = f_1(\mathrm{M}')$, whereas the true relation is $x = f(\mathrm{M})$; then, for example, if the rate of change of x with magnitude is required, the result is $dx/d\mathrm{M}'$ instead of $dx/d\mathrm{M}$, where by (13)

$$\frac{dx}{d\mathrm{M}'} = g\frac{dx}{d\mathrm{M}}.$$

If the dispersion in M for the stars considered is small, g may differ appreciably from unity. Thus for the group of giants referred to above, $g = 1 - f = 3/4$. As a practical consequence it becomes difficult to use even radial velocities for the investigation of the progression in stellar velocity within isolated groups such as the giants or dwarfs.

The influence in question is of course present in the case of tangential velocity discussed above, and appears explicitly as the first term on the right of (17) when this member is written as two fractions. The second term arises from the error in x, which in this instance indicates log T.

In accordance with a suggestion made by Professor Zernike of Gröningen, the restriction to Gaussian frequency functions thus far presupposed can be removed as follows: Equation (8) requires no such limitation. Assume, therefore, that F_1 is quite general, representing any type of frequency distribution whatever, and in both numerator and denominator replace the function by its development in Taylor's series. The function $\mathrm{F}_1(\mathrm{M}')$ and its derivatives thus introduced are constants as far as the integration is concerned. For the distribution of ϵ we need only assume $\mathrm{F}_2(+\epsilon) = \mathrm{F}_2(-\epsilon)$. Integrals involving odd powers of ϵ into $\mathrm{F}_2(\epsilon)$ then disappear. Further, introduce the ordinary mean square error through the relation

$$\bar{\epsilon}^2 \int_{-\infty}^{+\infty} \mathrm{F}_2(\epsilon)\,d\epsilon = \int_{-\infty}^{+\infty} \epsilon^2 \mathrm{F}_2(\epsilon)\,d\epsilon.$$

Equation (8) then becomes

$$\bar{\epsilon} = \overline{\mathrm{M}} - \overline{\mathrm{M}}' = \frac{\bar{\epsilon}^2 \mathrm{F}'_2(\mathrm{M}')}{\mathrm{F}_2(\mathrm{M}')}. \quad . \quad . \quad . \quad . \quad (18)$$

which is correct to terms of the third order, inclusive, in ϵ. For the special case of Gaussian distribution functions, $\bar{\epsilon}^2 = 1/2h^2$, and (18) reduces at once to the form (11).

The remaining assumption underlying both (11) and (18), namely, the independence of the errors of observation and the characteristic measured, should be examined in each special case. If not independent, the discussion must be modified accordingly.

From (18) it appears that $\bar{\epsilon}$ depends upon the slope of the frequency

curve within the interval covered by the observations which are combined into a mean—the flatter the curve, the smaller the error; and, if the slope is reversed, the error changes sign. This circumstance has a direct bearing upon the accuracy of the progression in log T given by Adams, Strömberg, and Joy in *Mt. Wilson Contribution* No. 210. If either the giants or the dwarfs are considered separately, serious errors in the calculated progressions are to be expected;* but if all the stars are discussed together, as was done in the solution based on the assumption of a continuous variation, the frequency function is no longer Gaussian, but becomes for the data used a curve of double maximum. The errors on the two sides of the same maximum therefore tend to compensate each other, so that the average value of the progression for the whole range in M is probably not seriously influenced.

Theoretically, the formulæ for $\bar{\epsilon}$ afford a simple method of freeing means of observed values of a characteristic from systematic error. In practice the matter is not so simple, as may be seen by considering the difficulties pointed out by Eddington and Miss Douglas in the case of stellar velocity.

Finally, it may be remarked that for cases in which the precision of measurement is within control, the formulæ indicate what accuracy must be attained in order that the results may be satisfactorily free from systematic error.

The Relation between Visual Star Colours and Spectral Classes.

By W. S. Franks.

The annexed table gives in a condensed form the result of analysis of 5793 stars in order to determine the *mean* colour equivalents of all classes of stellar spectra, from Oa to Nc. From B to M the material was entirely derived from the *Specola Vaticana*, 15, excluding all double stars and peculiar spectra, and any objects below $-25°$ declination. The number of stars thus dealt with is 5671. But for the O and N types, on account of their small number in the aforesaid work, recourse was had to the *Draper Catalogue* for a longer list.

Taking the O stars first, the number observed amounts to about half the total known; including a few brighter stars in the southern hemisphere, which were examined for me at the Union Observatory, Johannesburg. This type presents some peculiarities which may be mentioned. They only form about one-twentieth per cent. of known spectra; are almost entirely confined to the Milky Way; and two-thirds of them are south of the equator. Some of them are involved in nebulosity, such as θ^1 and ι Orionis, 15 Monocerotis, etc.; others are doubles or spectroscopic binaries. But the most singular feature is that many of them are arranged in *pairs*, of similar magnitude and spectral class, within about

* Adams and Strömberg, *Monthly Notices*, 83, 474, have described the method used to reduce these errors to a minimum.

1^c or so of each other; almost suggesting the idea that they had a common origin—perhaps being derived from the disruption of a parent body?

With regard to the B stars, it may be pointed out that the Helium lines attain their maximum intensity in classes B2 and B3, which coincides with the greatest percentage of *white* stars as observed visually; on either side of this dividing line there is a gradual increment of colour. In dealing with my own observations, I merged all cases of B^1 (bluish) and G^1 (greenish) into W (white); and treated YG^1 (yellowish-green) as Y$^{0\cdot5}$, the nearest equivalent on the continuous scale. It should also be stated that the B type is very unequally distributed, the galaxy hours of R.A. being crowded with such, whilst in the intervening mid-space they are few and far between.

The A stars form about one-fifth of the total, and their colour ranges from a pure white like that of *Sirius* or *Vega* up to a normal Y^1. Some of the F type, in fact, are whiter than others of the A group; nevertheless, their *mean* colour shows a gradual progression. The types from A to K are fairly even in distribution, the last named being the most frequent in point of numbers, and forms about one-third of the total.

The M stars are decidedly orange in colour, and many of them are also variable in their light; some of them, too, are nearly as richly tinted as stars of type N. Class Md consists entirely of *variable* stars, mostly of long period and extreme range of magnitude; their spectra may belong to any class of M, with the addition of bright lines. They were, therefore, excluded from the analysis. And class Mc was only represented by 6 stars in the aforesaid work, which was too small a number for a satisfactory result. So 30 extra stars were selected from the *Draper Catalogue*, and were observed specially for this investigation. In this instance the numerical equivalent was *calculated* on the basis of already-known data.

With regard to the N stars, on account of their specially interesting character, their vivid tints and variability, it was decided to make a comprehensive working list from the *Draper Catalogue*, and to observe *all* such objects north of -25° declination, taking 9·5 magnitude as the minimum limit. Up to the present time, about half the list has been observed, and sufficient material accumulated for the required purpose. But whatever may be the difference on the photographic plate, the classes Na and Nb are indistinguishable visually. The typical stars of each class look exactly alike to my eye, nor do the visual spectra of Dunér and others show any difference.

But class Nc is unmistakable in its superiority of tint, and these are the reddest of "red" stars. Even this must be qualified somewhat, as there is no such thing as a *pure* red in stellar tints. I should call the finest specimens of Nc an "intense orange red."

In conclusion I may mention that two-thirds of the N type stars are situated in or near the Milky Way, and that their total is only about one-tenth per cent. of known spectra. I should also state that stars marked Npec were excluded, as being generally referable to some class of R, an intermediate type between Md and Na.

Spectral Classes.	No. of Stars.	Visual Mean Colours. Kr-Ost.	Visual Mean Colours. Fr.	Class Per-centage.	Type Per-centage.	Total Stars.
Oa, Ob, Oc	16	...	$Y^{0\cdot5}$	...	...	53
Od, Oe	9	...	Y^{1}	...	...	
Oe5	28	2·60(12)	$Y^{0\cdot6}$	...	...	
Bo, B1	46	2·19	$Y^{0\cdot2}$	6·75		
B2, B3	192	2·10	W	28·15		
B5	89	2·09	$Y^{0\cdot2}$	13·05	12·02	682
B8	159	2·17	$Y^{0\cdot3}$	23·31		
B9	196	2·25	$Y^{0\cdot4}$	28·74		
Ao	496	2·22	$Y^{0\cdot3}$	44·60		
A2	315	2·44	$Y^{0\cdot6}$	28·43	19·61	1112
A3	150	2·63	$Y^{0\cdot8}$	13·48		
A5	151	2·93	Y^{1}	13·49		
Fo	259	3·29	$Y^{1\cdot2}$	37·00		
F2	105	3·40	$Y^{1\cdot3}$	15·00	12·34	700
F5	234	3·82	$Y^{1\cdot5}$	33·43		
F8	102	4·04	$Y^{1\cdot7}$	14·57		
Go	171	4·61	Y^{2}	28·84	10·46	593
G5	422	5·31	$Y^{2\cdot5}$	71·16		
Ko	1303	5·71	Y^{3}	62·34		
K2	360	6·06	OY	17·23	36·86	2090
K5	427	6·43	OY^{3}	20·43		
Ma	315	6·88	O^{2}	63·76		
Mb	143	7·18	$O^{2\cdot5}$	28·95	8·71	494
Mc	36	*7·60(6)	$O^{3\cdot2}$	7·29		
R	8	8·24(8)	OR^{2}	(Intermediate type)		8
Na	18	8·38(11)	$OR^{2\cdot5}$	...	...	61
Nb	33	8·35(19)	$OR^{2\cdot7}$	...	...	
Nc	10	8·56(5)	$OR^{3\cdot4}$	...	...	
	5793				Total	5793

* Calculated. Numbers within brackets are all for which linear equivalents could be found in Krüger's *Neuer Katalog* (1914) or *Indexkatalog* (1917). The two columns of mean colours are entirely independent of each other, and may not always coincide, though they are usually in close accordance.

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Herschel's $18\frac{3}{4}$*-in. Speculum* (*the* "20 *ft.*").

By Rev. C. D. P. Davies.

By the kindness of Miss Herschel I was privileged on June 26 last to test at Slough one of the three mirrors which Sir John Herschel took with him to the Cape, and with which he made there his celebrated observations of the southern heavens during the years 1834–38. The mirrors were "for use" in his "20-ft. telescope." While there he marked them with distinguishing Nos. I., II., III. The particular one which I tested, identified later by the finding of the small figure "3" on its edge, was therefore No. III., which Sir John described as having been made by his father and himself working together. Of the other two, No. II. was made by Sir William alone, and the remaining one, No. I., by Sir John alone.

Before giving the results of the testing of No. III. it may prove interesting to give a brief outline of its history, as gathered from the various allusions to it in the Notes and Memoranda.

From the fact that it was made by Sir William and Sir John working in conjunction, its date of origin can be fixed within fairly narrow limits.

Sir John Herschel was not born until 1792, and it is scarcely likely that he would be associated with his father in such a task as the grinding and figuring of a large mirror before the age of sixteen years or thereabouts. This brings us to 1808. Sir William died in 1822. We thus get a clear and definite limit on either side. From a rather hurried perusal of Sir William's record (MS.) of grinding and polishing work in the year 1818, and from the fact that in two instances, and apparently in these two only, he used the plural pronoun "we," both entries referring to the same mirror, it seems highly probable that by the "we" are meant Sir William and his son, and that the mirror on which they were at work was the one now in question. This would be when Sir John was twenty-six years of age—a highly probable period for work of this sort.

In the Notes kindly supplied to me the first actual mention of the *telescope* of which our mirror, if not then, at least later on, formed part, occurs in Sir John Herschel's diary under date 1820 December 15, where he says that he occupied the morning in "repairing the 20 ft." The instrument was set on the moon in the evening, and in a subsequent note it is stated that it continued in use throughout the succeeding year (1821). It was again put in order on 1822 April 1.

Then comes a long interval, and it is not until 1833 August 1 that we find mention of it once more. That mention is most brief and most interesting, viz., "Packing the 20 ft." He sailed for the Cape on November 13, and with him went our mirror packed, as stated in the "Cape Register of goods shipped," in an elm box.

At the Cape, which he reached on 1834 January 16, the mirrors seem to have preserved their efficiency for some months. But in August he says that his "two best" mirrors were so tarnished as to be useless. By the "two best" he evidently means No. I., which he made himself, which was the most recent, and which he more often than not calls

the "long-focussed one," and our No. III., usually called the "short-focussed one."

He therefore fitted up his "polishing apparatus," and in his subsequent Notes we find descriptions more or less full of the polishing of mirror No. III. Of these the following is a brief résumé :—

"1834 September 9.—Polished it. On trial on the following night (10th); it proved very successful." In the course of his note he gives us to understand that the mirror on some former occasion had not been improved by an attempt to clean its surface with citric acid.

It was again polished on 1834 December 8, and successively early in January, in the middle of June, and again in the middle of December 1835. It was polished yet again in 1836 November, and once more on 1837 April 12; his description of the result of the last being: "The polish was fine, and remarkably free from scratches, but the deeper tarnish spots were not quite effaced." The tarnish spots were apparently caused by the citric acid treatment.

In March 1838, Sir John sailed from the Cape, reaching England in May, the 20-ft. telescope having, as has been truly stated, "triumphantly accomplished the noble task for which it had been constructed."

So far as is known this telescope was never erected again, being taken in 1840 from Slough to Hawkhurst, where its tube lay through one vicissitude after another—including the death of Sir John Herschel in 1871, that of his widow in 1884, and even the departure of the family in 1888—until 1921, when it was reclaimed and brought back to its old home at Slough, our mirror, with all the other "belongings," having been brought back thither in the previous year (1920).

It was kindly placed on view for the visit of Fellows of the Society and others on 1922 August 25, the centenary of the death of Sir William Herschel.

It is always very delightful to find others interested in the Foucault test. In testing the mirror at Slough I had the pleasure of the presence of the Rev. Sir John Herschel and also of Dr. Steavenson, both of whom were keenly interested in the process throughout, and whose independent measures of the zones afforded me the great satisfaction of being in practical accordance with my own, the three sets of measures being mutually corroborative, and thus affording strong presumption of their accuracy.

In describing the testing it should be stated that the exact diameter of the mirror is 18·75 inches, the extra $\frac{3}{8}$ inch all round being doubtless designed to afford a clear aperture of 18 in., avoiding all risk of irregularities at or near to the edge. Had I known at the time that there had ever been "tarnish spots" on its surface, as shown by Sir John's notes at the Cape, I should have looked with especial care for any traces of them. As my impression was that the surface was in excellent condition I feel that it may safely be taken for granted that the spots had been practically obliterated.

The mirror, being very heavy, was not removed from its box, the box, with the mirror in it, being set up and secured in the position required. Diaphragms were employed with zones having radii of 8·875 in., 8·125 in., 5·375 in., and 2·5 in. The first of these (A) exposed a

zone of the mirror from a radius of 8·375 in. to the extreme edge. The other three, numbered I., II., III. respectively, exposed each of them a zone 2 inches broad, the mean or central radius of the zones being as given above.

The radius of curvature (R) of the mirror measured exactly 40 ft., making the length of the principal focus precisely 20 ft., in full accordance with the name always given to it by its owner.

In the formula

$$a = \frac{r^2}{R}$$

we thus get R = 480, while for the values of r^2 we get

A	78·765
I.	66·015
II.	28·890
III.	6·25

And for a

A	·164
I.	·137
II.	·060
III.	·013

Taking a as zero for A, and reckoning therefrom *towards* the mirror, we get the following values of a:—

A	·000
I.	·027
II.	·104
III.	·151

Or, in the event of irregularity at the extreme edge of the mirror causing uncertainty or difficulty in fixing the exact focus of the outermost zone,

Taking a as zero in I., we have

A	−·027
I.	·000
II.	·077
III.	·124

The actual measures are as follows:—

A	−·125
I.	·000
II.	·410
III.	·550

Or, if preferred, reducing these same measures to the zero of A,

A	·000
I.	·125
II.	·535
III.	·675

The measures taken by Rev. Sir John Herschel and Dr. Steavenson are :—

	Herschel.	Steavenson.
A	−·185	−·125
I.	·000	·000
II.	·400	·450
III.	·495	·550

both of which sets will be seen to be in practical accordance with my own measures, the greatest difference in any two readings of the same zone being that between Sir John's readings of A and III. and those of Dr. Steavenson and myself, viz. $\frac{3}{50}$ of an inch — not a very striking difference in a length of 40 ft.

At first sight it may seem that the measures indicate a rather serious departure from the perfect parabolic curve. Of course, the curve is deeper than theory indicates, that is to say, the mirror is hyperbolic. But when it is borne in mind that in the days when it was made the principle of testing at the centre of curvature was unknown, and that even when tested by this more recent and minutely accurate method the greatest difference of focal length amounts to no more than ·426 inch; and when it is further remembered that testing at the principal focus was the only test at the disposal of the men of that day, and that such test was only one quarter as powerful as the Foucault test, that is, that the error, so far as they could read it, and, we may add, so far as concerns the actual use of the mirror, amounted to just about one-tenth of an inch, it is impossible not to be filled with admiration for their work.

But this is not all. As yet I have spoken only of the zonal testing. The other portion of the Foucault test, that in which the appearance of the mirror is judged as a whole, in contradistinction to its piecemeal examination zone by zone, that generally known as the "shadow" test, reveals in the case of this historic speculum a remarkable regularity of curvature throughout. There is a complete absence of rings, sudden gradations, mounds, or pools, the shadow coming on and going off with the motion to or fro of the shutter just as it should do. Altogether the mirror is a grand specimen of the work of the two great men who produced it, and is one more proof, if such were needed, of the sureness and soundness of the foundations on which rest the undying reputations of Sir William and Sir John Herschel.

Stellar Parallaxes determined at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The following list is a continuation of the results obtained with the 26-inch telescope.

In the column Proper Motion the first value given is from meridian observations; the second is the relative proper motion derived from the photographs. The motions in both R.A. and Dec. are expressed in arc of a great circle.

In calculating the parallax, the relative proper motion is used, *not* the meridian proper motion.

The Probable Error has been calculated by the formula

$$r = 0{\cdot}6745 \times \sqrt{\frac{[vv]}{m-\mu}} \times \frac{1}{\sqrt{w}}.$$

The first given is the P.E. of the parallax, the second is the P.E. of the relative proper motion and applies to both R.A. and Dec. when the latter is given.

Generally six comparison stars of mean magnitude 11–12 have been used, the magnitude of the parallax star being reduced to equality by means of the rotating sector.

For the brighter stars a supplementary neutral tinted filter has been employed in conjunction with the shutter. The parallax of Polaris was thus obtained by direct comparison with stars of the 12th magnitude.

Name and B.D. No.	Mag. Vis. Photog.	Spectral Type.	R.A. Dec. 1900·0.	Proper Motion. R.A.	Proper Motion. Dec.	Parallax.	P.E.	No. of Plates.
	m		h m s	″	″	″	″	
78° 17	9·1		0 28 49	+ ·179	−·036	+·003	±·006	20
	9·9		+78° 43′	+ ·176	−·014		±·002	
Gr. 126	7·9	G5	0 38 12	+ ·393	−·103	+·010	±·008	22
75° 36	7·6		+75° 24′	+ ·385	−·095		±·002	
O.A. 873	9·1	K	0 50 23	+ ·729	−·225	+·012	±·008	21
68° 60	9·6		+68° 31′	+ ·708	−·239		±·003	
Chr. 233	9·3		1 9 27	+ ·060	−·140	+·003	±·007	26
	10·5		+67° 40′	+ ·033	−·062		±·003	
Polaris	2·0	F8	1 22 34	+ ·046	+·003	−·005	±·005	31
88° 8	2·7		+88° 46′	+ ·048			±·006	
71° 145	9·1		2 21 22	+ ·326	−·153	−·004	±·006	19
	9·2		+71° 44′	+ ·291			±·005	
N.P.C. 353	..		2 50 38	+ ·220	−·130	+·002	±·007	24
	11·3		+89° 26′	+ ·188			±·006	
72° 181	9·0	K0	3 26 20	+ ·201	−·151	+·019	±·005	21
	10·0		+72° 45′	+ ·206			±·005	

No.	Name and B.D. No.	Mag. Vis. Photog.	Spectral Type.	R.A. Dec. 1900·0.	Proper Motion. R.A.	Proper Motion. Dec.	Parallax.	P.E.	No. of Plates.
		m		h m s	″	″	″	″	
9	66° 355	9·2		4 40 48	−·186	−·146	+·024	±·007	24
		9·4		+67° 0′	−·158			±·005	
10	68° 394	9·4		5 26 37	+·262	−·141	+·020	±·005	25
		9·7		+68° 40′	+·244			±·006	
11	A.C. 69° 3055	..		6 40 57	−·037	−·199	+·015	±·006	21
		10·4		+69° 10′	−·011			±·005	
12	A.C. 77° 3083	..		7 18 51	+·238	−·231	+·010	±·005	25
		10·6		+77° 8′	+·267			±·005	
13	86° 118	9·5		8 12 44	−·054	−·221	+·021	±·006	25
		11·0		+86° 1′	−·057			±·005	
14	O.A. 8869	8·8	K0	8 16 21	+·016	−·512	+·030	±·005	27
	66° 550	9·2		+66° 48′	+·009	−·501		±·002	
15	68° 557	8·0	F5	9 2 11	−·107	−·143	+·013	±·006	23
		7·8		+67° 52′	−·134	−·151		±·002	
16	83° 264	9·5		9 35 56	−·142	−·202	−·001	±·007	19
		10·8, 11·3		+83° 25′	−·123			±·005	
17	69° 558	8·8	G5	10 0 45	−·251	−·123	+·023	±·005	20
		9·1		+68° 56′	−·260			±·004	
18	69° 572	9·0		10 19 54	+·182	−·037	+·030	±·006	23
		9·8		+69° 22′	+·162			±·004	
19	68° 620	9·5		10 44 54	−·195	−·255	+·021	±·008	20
		10·5		+68° 7′	−·165			±·007	
20	75° 436	9·5		11 3 25	−·286	−·046	+·017	±·006	22
		10·1		+75° 4′	−·281			±·006	
21	O.A. 11677	9·0	Ma.	11 14 53	−2·957	+·203	+·122	±·008	25
	66° 717	10·3		+66° 23′	−2·942			±·006	
22	74° 476	6·7	F8	11 48 19	−·043	−·079	+·035	±·009	23
		7·0		+74° 19′	−·043			±·008	
23	84° 263	9·5		11 59 36	−·263	+·088	+·033	±·007	22
		11·3		+84° 0′	−·238			±·006	
24	O.A. 12584	8·0	G5	12 17 55	−·477	+·203	+·031	±·008	26
	74° 493	8·5		+73° 48′	−·432			±·005	
25	O.A. 12816	9·0		12 32 35	+·293	−·244	+·032	±·007	25
	78° 428	9·4		+78° 7′	+·280			±·004	

Name and B.D. No.	Mag. Vis.	Mag. Photog.	Spectral Type.	R.A. Dec. 1900·0.	Proper Motion. R.A.	Proper Motion. Dec.	Parallax.	P.E.	No. of Plates.
	m	m		h m s	″	″	″	″	
85° 223	9·2			13 20 51	+ ·209	−·083	+·013	±·007	23
		9·8		+85° 14′	+ ·272			±·005	
75° 510	9·5			13 31 4	− ·423	−·030	+·038	±·008	20
	11·1			+75° 31′	− ·417			±·005	
65° 962	9·1			13 45 40	− ·197	+·033	+·008	±·006	24
		9·6		+65° 42′	− ·155			±·003	
86° 197	9·5			13 48 36	− ·231	−·032	+·026	±·006	26
	11·3			+86° 8′	− ·264			±·003	
A.C. 72° 6399	..			14 52 4	− ·830	−·395	+·018	±·007	23
	11·5			+72° 6′	− ·866			±·006	
65° 1050	9·5			15 20 28	− ·087	−·121	+·028	±·008	23
	10·0			+65° 33′	− ·081			±·005	
77° 584	9·1			15 22 51	− ·234	+·293	+·017	±·007	23
		9·6		+77° 29′	− ·245			±·004	
L.F. 2684	8·2		G0	15 31 48	+ ·225	+·039	+·013	±·009	18
82° 456	7·9			+82° 14′	+ ·208	+·013		±·002	
A.C. 67° 5226	..			16 16 34	..		+·083	±·008	26
	11·5			+67° 29′	− ·475			±·003	
65° 1122	7·2		G0	16 28 19	− ·151	+·116	+·027	±·009	27
		7·9		+65° 0′	− ·136			±·007	
79° 642	9·4			19 46 4	+ ·223	+·182	+·005	±·011	21
	10·6			+79° 28′	+ ·200			±·009	
68° 1095	8·8		G5	19 58 6	+ ·185	+·129	+·012	±·009	21
		9·5		+68° 52′	+ ·143			±·008	
76° 810	9·5			20 40 19	− ·072	−·199	+·010	±·007	24
	10·5			+76° 53′	− ·034			±·004	
68° 1155	8·3		G5	20 44 53	+ ·142	+·142	+·016	±·007	22
		8·7		+68° 11′	+ ·102			±·005	
65° 1512	9·5			20 50 44	+ ·238	+·298	+·026	±·008	21
	10·9			+65° 54′	+ ·284			±·006	
Carr. 3218	8·8		F8	20 59 0	+ ·256	−·071	−·008	±·008	24
85° 357	9·1			+85° 11′	+ ·257	−·089		±·002	
O.A. 21804	8·5			21 4 22	+ ·119	+·186	+·004	±·006	22
78° 438	9·0			+78° 54′	+ ·112	+·176		±·002	

No.	Name and B.D. No.	Mag. Vis. Photog.	Spectral Type.	R.A. Dec. 1900·0	Proper Motion. R.A.	Proper Motion. Dec.	Parallax.	P.E.	No. of Plat
		m		h m s	″	″	″	″	
43	L.F. 3738	8·8	Ko	21 8 48	− ·336	−·368	+·023	±·008	2
	73° 925	9·0		+73° 18′	− ·350	−·408		±·002	
44	L.F.$_2$ 286	8·9	Ko	21 47 18	+ ·344	+·050	+·032	±·008	2
	83° 617	9·0		+83° 52′	+ ·328			±·002	
45	L.F. 4014	8·8	G5	22 0 8	+ ·134	+·200	−·011	±·007	2
	67° 1386	9·3		+67° 46′	+ ·126			±·002	
46	Carr. 3438	8·3	G5	22 22 15	+ ·304	+·025	+·035	±·008	2
	82° 689	8·8		+83° 2′	+ ·298	+·027		±·002	
47	L.F. 4235	7·1	G5	22 37 29	+ ·218	+·396	+·026	±·007	2
	65° 1796	7·7		+65° 59′	+ ·221	+·397		±·002	
48	63° 1882	7·7	Go	22 40 30	+ ·054	−·327	+·035	±·007	2
		7·9		+64° 3′	+ ·039	−·300		±·002	
49	Gr. 4047	7·7	G5	23 16 15	+ ·205	−·078	+·018	±·011	2
	78° 826	8·1		+78° 27′	+ ·218			±·007	
50	76° 944	9·0	Ao	23 54 44	..	..	+·001	±·008	2
		8·8		+76° 45′	+ ·012	+·013		±·006	

Notes.

No. 7. *N.P.C.* = *Greenwich North Polar Catalogue.*
Nos. 11, 12, 30, 34. *A.C.* = *Astrographic Catalogue.*
No. 16. Double star as a mean. Angle 45°, Dist. 1″·6. As the components were sometimes not properly separated, they were measured individually as well as possible and the mean of the measures taken.
No. 50. Put on observing list through being erroneously credited with a large P.M.

Mean Areas and Heliographic Latitudes of Sunspots in the Year 1922.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those in the *Monthly Notices*, **83**, 400, and are derived from the measurement of photographs taken at the Royal Observatories of Greenwich and the Cape, and in India at Kodaikánal Observatory and at Dehra Dûn.

Table I. gives the mean daily area of umbræ, whole spots, and faculæ for each synodic rotation of the Sun for the year 1922, and Table II. gives the same particulars for each entire year from 1913 to 1922 inclusive. The areas are given in two forms: firstly, projected areas, *i.e.* as seen and measured on the photographs, these being expressed in millionths of the Sun's apparent disc; secondly, areas

corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. gives for each rotation in the year 1922 the mean daily area of the whole spots (corrected for foreshortening) and the mean heliographic latitude of the spotted areas for spots north and for spots south of the equator, together with the mean heliographic latitude of the entire spotted area and the mean distance from the equator of all spots. Table IV. gives the same information for each year as a whole from 1913 to 1922. Tables II. and IV. are thus in continuation of similar tables for the years 1874 to 1888 on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*; for the years 1889 to 1902 on pp. 465 and 466 of vol. lxiii.; and for the years 1901 to 1914 on pp. 402 and 403 of vol. lxxvi.

The rotations in Tables I. and III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon of 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days.

The principal features of the record for the year 1922 were as follows:—

1. The definite progression of the solar cycle towards minimum shown by the decrease of the mean daily area of spots—252 units as compared with 420 units in the year 1921 and 1537 units in 1917, the maximum year of the cycle.

2. A proportionate decrease in the amount of faculæ, which in general corresponds with the spot curve.

3. The northern hemisphere showed the greater activity, mainly due to three large spot-groups seen during rotation 915, and to another group in rotation 926. No spots were recorded in the southern hemisphere during rotation 918.

4. The mean latitude (8°) of the spots was about the same as for 1921. In previous cycles this latitude was reached about a year before the minimum. A small spot in high southern latitude (41°) was visible on November 14 and 15. Two other small high latitude spots seen on one day only were also recorded—one on June 19 in latitude 33° N., the other in latitude 31° N. on June 24. These are apparently the forerunners of the new cycle.

5. During the year, two-thirds of the spot-groups were confined to one-half of the Sun, between longitudes 330° – 0° – 130°. The region between longitudes 130° and 330° contained the remainder, but, with two exceptions, these groups were all very small and usually short-lived.

6. On 109 days no spots were visible on the disc, as compared with 31 days in the previous year.

7. The number of separate groups lasting for at least two days was 76 as compared with 129 for the year 1921. Of these 76 groups, 47 were in the northern hemisphere and 29 in the southern. Besides these, there were recorded 58 small groups (mostly consisting of one or two very small spots) visible for one day only; 27 were in the northern and 38 were in the southern hemisphere.

TABLE I.

No. of Rotation.	Rotation commenced G.M.T. (Civil).	No. of Days on which Sun photographed.	Mean of Daily Areas. Projected. Umbræ.	Whole Spots.	Faculæ.	Corrected for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
	1921–22 d							
913	Dec. 18·97	27	66	325	494	46	239	594
914	Jan. 15·30	28	39	186	354	25	121	410
915	Feb. 11·64	27	359	2038	734	259	1487	889
916	Mar. 10·98	27	93	593	899	68	418	1015
917	Apr. 7·28	28	35	177	539	21	108	615
918	May 4·53	27	16	78	421	13	69	474
919	May 31·75	27	6	24	281	5	18	327
920	June 27·94	27	37	180	218	22	106	250
921	July 25·15	28	8	40	160	7	33	178
922	Aug. 21·38	27	28	145	173	23	126	221
923	Sept. 17·63	27	15	69	150	11	49	171
924	Oct. 14·92	27	26	143	170	23	137	203
925	Nov. 11·21	28	43	244	215	32	183	241
926	Dec. 8·53	27	135	760	322	99	572	363

TABLE II.

Year.	No. of Days on which Sun photographed.	Mean of Daily Areas. Projected. Umbræ.	Whole Spots.	Faculæ.	Corrected for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
1913	365	2	10	87	1	7	95
1914	365	40	195	396	31	152	454
1915	365	186	920	1289	137	697	1521
1916	365	186	978	1512	135	724	1785
1917	365	346	2101	1882	247	1537	2305
1918	364	255	1504	1526	188	1118	1882
1919	365	253	1437	1445	182	1052	1729
1920	366	156	837	1052	112	618	1219
1921	365	110	571	647	79	420	743
1922	365	63	346	358	45	252	415

TABLE III.

No. of Rotation.	Rotation commenced G.M.T. (Civil).	Spots NORTH of the Equator. Mean of Daily Areas.	Spots NORTH of the Equator. Mean Heliographic Latitude.	Spots SOUTH of the Equator. Mean of Daily Areas.	Spots SOUTH of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of entire Spotted Area.	Mean Distance from Equator of all Spots.
	1921–22 d						
913	Dec. 18·97	76	9°·22	163	5°·64	−0°·93	6°·78
914	Jan. 15·30	49	10·05	72	6·55	+0·20	7·97
915	Feb. 11·64	1122	9·92	365	6·19	+5·97	9·01
916	Mar. 10·98	277	9·31	141	6·69	+3·90	8·42
917	Apr. 7·28	106	8·19	2	11·12	+7·91	8·23
918	May 4·53	69	8·50	0	...	+8·50	8·50
919	May 31·75	11	8·83	7	8·29	+2·38	8·63
920	June 27·94	14	10·17	92	6·20	−4·07	6·71
921	July 25·15	5	10·08	28	6·08	−3·62	6·69
922	Aug. 21·38	23	4·22	103	12·00	−8·99	10·56
923	Sept. 17·63	14	14·29	35	11·39	−3·99	12·23
924	Oct. 14·92	5	12·34	132	6·49	−5·87	6·69
925	Nov. 11·21	5	4·67	179	4·42	−4·18	4·43
926	Dec. 8·53	542	5·95	30	3·50	+5·46	5·83

TABLE IV.

Year.	No. of Days on which Sun photographed.	Spots NORTH of the Equator. Mean of Daily Areas.	Spots NORTH of the Equator. Mean Heliographic Latitude.	Spots SOUTH of the Equator. Mean of Daily Areas.	Spots SOUTH of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of entire Spotted Area.	Mean Distance from Equator of all Spots.
1913	365	5	24°·81	2½	20°·08	+9°·81	23°·23
1914	365	99	21·11	53	23·06	+5·71	21·79
1915	365	379	17·95	318	19·75	+0·77	18·77
1916	365	470	15·14	254	17·05	+3·83	15·81
1917	365	860	13·82	677	15·66	+0·84	14·63
1918	364	609	11·97	509	13·69	+0·29	12·75
1919	365	559	9·85	493	11·79	−0·28	10·76
1920	366	208	11·31	410	9·98	−2·83	10·43
1921	365	261	7·27	159	8·92	+1·13	7·90
1922	365	161	8·82	91	6·62	+3·23	8·02

Royal Observatory, Greenwich:
1923 *October* 23.

RW Sagittarii. By P. M. Ryves.

The variability of this star, which is B.D. − 19° 5347, was discovered by Mrs. Fleming in 1896.

Harvard "Second Catalogue of Variable Stars" (1907) contains the statement: "Measures of Harvard photographs, extending from August 16, 1889, to October 6, 1904, show that the period is probably irregular, although a period of 300 to 400 days is sometimes indicated." The visual range is there given as $9^{m}\cdot0$ to $11^{m}\cdot7$. A few years later RW Sagittarii was being marked "Kurze Periode?" in Hartwig's annual ephemeris, range $9^{m}\cdot2$ to $10^{m}\cdot0$.

Observations were commenced by the writer in the summer of 1910 and continued till the summer of 1914. The general character of the variation has been deduced from this series, a further short series, made in 1922–23, having been used to check the period—in all 135 observations.

The Comparison Stars.—The following table contains particulars of eight convenient comparison stars:—

Des.	R.A. 1900	Dec. 1900.	Grades.	Phtm. Mag.	Adopted.
	h m	° ′	G.	m	m
b	19 08·8	− 19 10	0	8·4	8·30
c	19 07·5	− 19 03	2·5	...	8·57
d	19 07·5	− 18 45	10·8	9·6	9·50
f	19 08·1	− 19 08	13·5	9·9	9·78
g	19 08·3	− 19 13	18·0	...	10·28
h	19 07·8	− 18 52	20·3	...	10·53
k	19 08·2	− 18 51	22·0	10·8	10·72
l	19 08·0	− 18 54	25·1	11·1	11·06
RW	19 08·0	− 19 02	...	...	...

The positions are given with sufficient accuracy for identification; the grades were obtained by means of 66 direct comparisons (comparison star with comparison star) and 88 using the variable as intermediary; the photometer magnitudes were supplied by the late Professor E. C. Pickering. The adopted magnitude of *b* has been arrived at through comparisons with neighbouring stars combined with the Harvard value; the adopted magnitudes of the remaining stars have been obtained from the formula $M = 8\cdot30 + 0\cdot11G$, a linear solution being satisfactory. For *c* the magnitude 9·5 was given by Harvard. This is nearly a whole magnitude fainter than the observed brightness. The star has been watched but, though the residuals were rather large at first, variation sufficient to account for the discrepancy has not been observed.

The observations do not appear to be affected by personal scale errors. Two sets of triplets show a satisfactory agreement between estimates of larger and smaller intervals.

Triplets.

G.		G.	
$(d-b)_{14}$	= 10·1	$(k-f)_{15}$	= 8·9
$(c-b)_{7}+(d-c)_{16}$	= 10·4	$(h-f)_{12}+(k-h)_{10}$	= 8·6

The subscript figures indicate the number of estimates.

Results of the Observations.—Besides being rather far south of the equator for observation at this station, RW Sagittarii is within 3° of the ecliptic. There are thus considerable seasonal gaps in the series, the length of which depend to some extent on the weather conditions prevailing at the critical times—late autumn and early spring. Further, the period which emerges is so nearly half a year that only alternate epochs can be well observed. When the period is applied, however, the various portions of the light-curve fit in and are consistent with

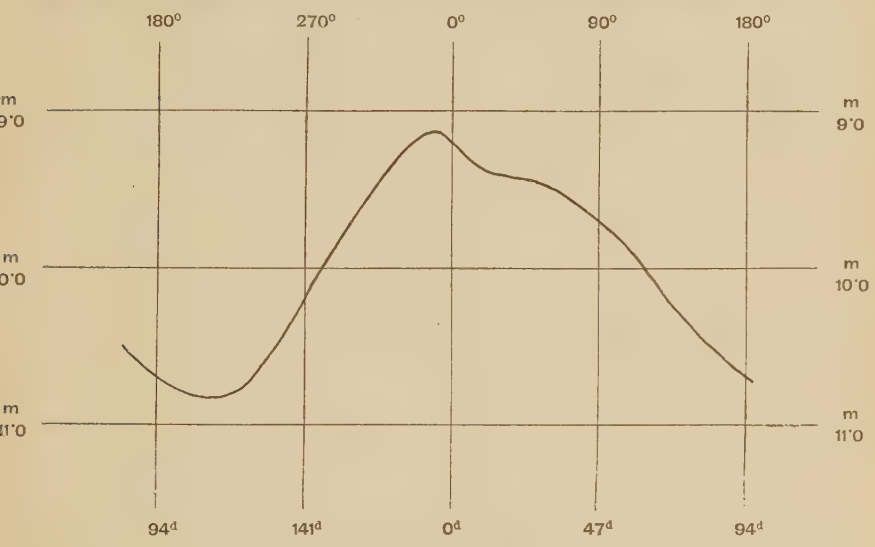

Fig. 1.—RW. Sagittarii. Mean Light Curve.

a *long-period* type of variation. The following elements satisfy the observations very well:—

$$\text{Max.} = \text{J.D. } 2418720 + 188E.$$

It does not seem advisable to attempt greater precision until more material is available. The extreme observed range is $2^{m}\cdot1$ (from $8^{m}\cdot8$ to $10^{m}\cdot9$), the mean range about $1\cdot7$ ($9^{m}\cdot1$ to $10^{m}\cdot8$). The rise occupies 76 days $\pm$, $\frac{M-m}{P} = 0\cdot4$.

The shape of the light-curve differs considerably at different epochs. Some of the maxima are narrow and pointed, others very broad and flat, the latter being the fainter. There is a tendency for consecutive maxima to be dissimilar but no regular alternation can be traced.

Fig. 1 shows the mean light-curve for the time. It must be remembered, however, that in the case of this star (and a good many others) the term "mean light-curve" has no very precise meaning, since its shape will depend upon what particular epochs are covered. In fig. 2

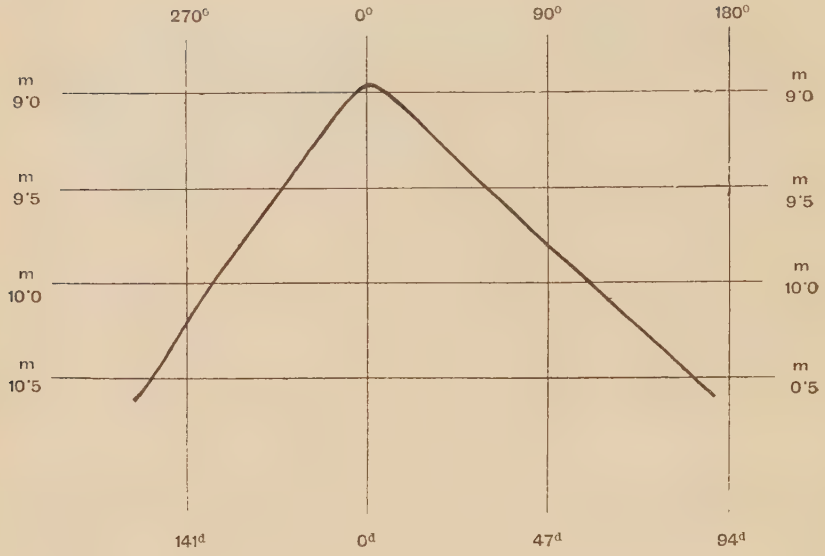

FIG. 2.—Narrow Maximum.

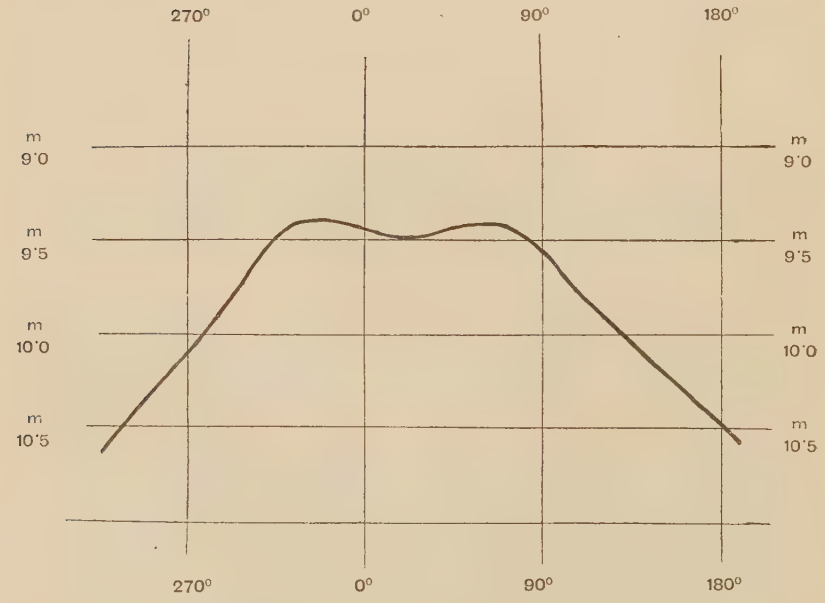

FIG. 3.—Broad Maximum.

one complete curve and several fragments are combined according to phase to represent a typical narrow maximum (E 4, 6, 7, 9). A similar combination of broad maxima is shown in fig. 3 (E 2, 3, 8 (25)). A maximum with two peaks has not been actually observed.

Further discussion may be reserved till more observations have accumulated.

Summary.

Observations of RW Sagittarii (*190819a*) made in 1910–14 (1922–23) show the star to be a variable of *long period* (188 days) and small amplitude (visual $1^{m}\cdot7$, mean; $2^{m}\cdot1$, extreme).

Provisional elements are given.

Positions and magnitudes of comparison stars and a mean light-curve are appended.

Zaragoza, Spain:
1923 *October* 30.

Stationary Meteors and Meteors nearly Stationary observed at Bristol since 1879. By W. F. Denning.

The following meteors were observed at Bristol to be stationary, or very nearly so, subsequently to the year 1879, when I published a list in the *Monthly Notices*.

It is believed that this class of object affords valuable evidence as to the positions of radiant points of meteoric showers. This is particularly the case when a meteor is seen to be absolutely stationary, and to shine like a fixed star at the place of its appearance.

Others, very nearly stationary, are also of great utility, since the radiant can be put a little back in the direction of flight, and found with almost equal certainty and accuracy.

The positions of stationary meteors in combination with the radiants found for ordinary shower-meteors, and with the radiants derived from doubly observed paths, serve to yield mean radiant positions which are as indisputable as they are accurate, and especially so when they are determined by observers of experience not influenced by any considerations other than to ascertain the facts of observation untrammelled by mathematical prejudices. The positions are nearly all selected as being reliable and indicating accurate radiants. The nearly stationary meteors can be depended upon almost as confidently as the others, as they were observed with critical care and all the details useful as guides given due weight. Many of them belonged to well-known radiants or to radiants determined from other ordinary meteors seen on the same night, or within two or three nights of the time when they were recorded.

It happens occasionally that a very short meteor is not always near its radiant. Meteors usually brighten up for one or two degrees near their end points, so that a 7th mag. object may be traceable by the eye just at max. as a very short meteor only.

The details of aspect here come in and enable the discerning observer

to discriminate between the *really foreshortened* meteors and the blaze-up section of normal flights of faint objects. Meteors nearly stationary are usually slow, often display a curling or tortuous movement, or are seen under a fuzzy aspect due to the streak or train lying nearly end on, and causing a brushy or blurred appearance which is quite obvious and unfailing in its teachings.

Stationary Meteors recorded at Bristol.

Year.	Date.	G.M.T. h m	Mag.	Radiant. c °	Notes.	Ref. No.
1920	Oct. 6	8 47	1	2 − 1	Sta. v. slow.	1
1916	Oct. 25	8 9	4	4 − 2	Sta. point.	2
1917	Sept. 12	9 19	4	5 +12	Slight motion, v. v. slow. R. 5°+11°.	3
1888	July 13	12 49	4	6 +12	N. sta.	4
1886	Aug. 27	10 52	2	7 + 6	Short, curled. R. 7°+11°.	5
1885	Oct. 7	9 17	3	9 +45½	N. sta. R. 5°+44°.	6
1918	July 16	13 11	1	11 +42½	N. sta. b.k.	7
1915	Oct. 13	11 2	5	11½+ 4	Slight motion. R. 13°+6°.	8
1921	July 5	11 17	3	14 +47	Sta. R.	9
1921	July 9	13 32	2	21 +16	N. sta.	10
1919	Sept. 29	10 4	4	23 +42	Sta. W.	11
1885	Nov. 27	5 35	3	23 +43½	Sta.	12
1900	July 24	12 18	4	23 +43	Motionless. =11, 12.	13
1884	Aug. 20	11 2	3	27 +34½	V. short. 30°+37°.	14
1917	Oct. 16	15 50	1	28 + 3	Sta.	15
1913	Aug. 25	11 32	1	28 +35½	Behind cloud, sta.	16
1885	Dec. 4	8 56	4	30 +34½	V. short. R. 31°+37°.	17
1917	Oct. 9	10 29	2	30 −5½	Apparently sta.	18
1903	Sept. 23	12 27	3	30 +17	N. sta. R. 29°+18°.	19
1913	Nov. 21	11 11	2	30 +65	N. sta.	20
1901	Aug. 21	13 53	5	30½ +15½	Slight motion. R. 33°+18°.	21
1918	Nov. 5	11 38	1	30½ +37	Sta. slow. =16, 17.	22
1886	Nov. 29	12 29	1	31 +16	R.W. n. sta. R. 32°+18°.	23
1888	Aug. 2	12 48	2	31¼ +17½	Slow, n. sta. R. 32°+19°.	24
1886	Aug. 4	14 11	3	31½+15	V. short. R. 32°+17½°. =19, 21, 23, 24.	25
1920	Sept. 12	10 57	>1	34 + 9	Sta. v. slow.	26
1917	Mar. 24	13 6	2	40 +72	V. short from Polaris.	27
1903	Oct. 23	11 25	3	41 +19	R. 40°+20°.	28
1899	Aug. 9	11 48	1	41 +23	N. sta. R. 40°+22¾°.	29
1918	Sept. 6	10 17	3	42 +39	Sta.	30
1886	Aug. 4	12 8	2	42 +20	No path, sta.	31
1893	Aug. 10	11 43	♀	42 +55	V. short. R. 44°+57°. Perseid.	32

Stationary Meteors recorded at Bristol—continued.

Year.	Date.	G.M.T. h m	Mag.	Radiant. ° °	Notes.	Ref. No.
1921	Nov. 6	11 10	4	42½+21	V. slow and slight motion.	33
1914	Nov. 16	8 59	5	43 +21	Almost sta.	34
1919	Nov. 21	9 10	3	43 +26	Sta. sl. W.	35
1887	Aug. 23	11 56	2	43 +39	Sta. K. β Perseid.	36
1886	Aug. 10	10 36	3	43 +58	Sta. sl. K. Perseid.	37
1902	Sept. 3	12 36	4	44 +56½	Motion ½°. R. 43°+56°. Perseid.	38
1897	July 29	13 25	2	44 +37	Sta. K. β Perseid.	39
1880	Aug. 10	11 28	3	44 +59	N. sta. R. 44°+58°. Perseid.	40
1918	Oct. 12	11 25	6	45 +20	Slight motion. R. 42°+21°. =28, 29, 31, 33, 34, ? 35.	41
1887	Aug. 1	13 4	2	48 +27	Sta. slow.	42
1887	Sept. 13	11 14	4	48 +43	Sl. n. sta. $\alpha-\beta$ Perseid.	43
1899	Aug. 13	11 27	3	49 +45	V. short streak. R. 48°+44°. $\alpha-\beta$ Perseid.	44
1880	Aug. 9	11 11	2	49 +58	Slight motion. R. 44°+57°.	45
1886	Nov. 17	8 52	4	53 +71	Sta.	46
1916	Aug. 10	11 21	2	57 +45	Sta.	47
1914	Aug. 17	10 46	2	57 +63	Nearly sta. Perseid.	48
1880	Aug. 9	11 56	1	59 +27	Sta.	49
1900	Aug. 17	11 21	2	59 +47	Sta. swift. White.	50
1885	Nov. 30	8 32	2	60 +49	R. sta.	51
1902	Aug. 10	13 26	4	60 +35	Very slight motion. ε Perseid.	52
1876	Nov. 20	9 47	2	61 +22	N. sta. R. 63°+23°.	53
1918	Aug. 31	15 6	4	63½+34	N. sta. ε Perseid.	54
1904	July 18	10 55	2	69 +52	R. b.w. sta.	55
1916	Aug. 27	6 46	2	70 +81	V. sl. nearly sta.	56
1887	Sept. 22	10 13	3	71 +49	N. sta. sl. K.	57
1916	Oct. 25	15 13	5	72 +67	Slight motion, streak. R. 72°+66°.	58
1914	Aug. 11	11 45	2	72 +59	Sl. R. 72°+65°.	59
1919	Oct. 18	15 31	5	91 +15	Sl. R. 91½°+15½°. Orionid.	60
1900	Oct. 26	10 59	4	91 +15	N. sta. R. 91°+15°. Orionid.	61
1917	Oct. 26	15 54	5	92 +21	N. sta. R. 93°+22°.	62
1917	Oct. 26	17 25	4	92 +20½	Path 1°. R. 92½°+21°.	63
1914	Oct. 26	14 6	2	96 +45	Slight motion, streak. R. 99°+44°.	64
1903	Oct. 22	15 45	5	104½+32	N. sta. R. 103°+33°.	65
1914	Sept. 21	11 27	1	105 +50	Almost sta.	66
1903	Oct. 22	10 33	4	106 +59	Almost sta.	67
1885	Dec. 10	12 19	4	107 +31½	N. sta. R. 109°+33°. Geminid.	68
1885	Dec. 11	11 58	4	107½+31½	N. sta. R. 109°+33°. Geminid.	69

Stationary Meteors recorded at Bristol—continued.

Year.	Date.	G.M.T. h m	Mag.	Radiant. ° °	Notes.	Ref. No.
1887	July 22	10 35	1	110 +50	Sta. =66.	70
1886	Dec. 24	10 55	3	129 +21	R.W. sta.	71
1887	Oct. 12	11 5	2	132 +43	R.W. sta.	72
1913	Mar. 8	11 14	2	135 + 9	Sta.	73
1913	Nov. 18	7 4	2	136 +76	Path 1°. Slow. R. 136°+78°.	74
1902	Oct. 16	16 50	2	136 +33	Almost sta. streak. R. 136°+33°.	75
1917	Mar. 15	9 4	4	140 +67	Path 1°. R. 140°+65°.	76
1903	Nov. 15	18 1	2	151 +23	Slight motion. Leonid.	77
1885	Dec. 10	12 23	2	153 +43	N. sta. R. 152+°40°.	78
1901	Dec. 10	15 4	5	157½ +15	N. sta. R. 155°+14°.	79
1911	Jan. 30	9 46	1	158 +41	N. sta. R. 156°+42°. =78.	80
1915	Apr. 14	9 23	>2	160 +57	V. sl. n. sta. R. 159°+57½°.	81
1913	Nov. 3	9 23	3	162 +73	V. short. R. 165°+73½°.	82
1918	Dec. 6	12 45	1	163 +74	N. sta.	83
1887	Jan. 25	11 29	4	170 +19	Slow.	84
1911	Mar. 4	10 31	2	170¼+ 0	Path 1°. V. slow. R. 171°+4°.	85
1918	July 3	11 31	2	171 +70	Sta. v. slow.	86
1909	Apr. 18	9 42	4	170 + 5	V. slight motion.	87
1886	Mar. 3	9 44	2	176 + 9	Sta.	88
1911	Mar. 4	9 0	4	176 +46	Path 1°. R.W. R. 175°+45°.	89
1887	Jan. 25	11 36	1	180 +24	Sta. R.	90
1915	May 9	10 20	2	195 +69	Path 1°. R. 197°+72°.	91
1902	Apr. 1	11 0	3	202 −10	Sta.	92
1887	June 26	12 21	2	213 +53	R. sta.	93
1905	Mar. 30	11 49	3	224 +41	N. sta. R. 222°+40°.	94
1917	Dec. 22	15 29	2	227 +50 to 227 +49½	½°. N. sta.	95
1887	Mar. 27	10 28	3	229 +32	Sta.	96
1917	May 22	10 19	1	229 − 6	N. sta. R. 229°−6°.	97
1917	Dec. 21	17 33	4	232 +54	Sta. Early quadrantid.	98
1915	Sept. 6	8 16	3	234 +17	Path 1°. R. 237°+19°.	99
1911	May 28	11 48	2	240 +46	Motionless or nearly so. Yellow.	100
1887	May 13	10 38	3	244 +30	Sta. R.	101
1889	Apr. 21	11 18½	2	247 +63	V. slight motion from α Draconis.	102
1903	May 24	11 3	2	248 +59½	Almost sta. R. 246°+63°. =102.	103
1888	Nov. 26	9 46	1	256 +67	Sta. slow.	104
1912	June 11	11 12	3	262 +37	Path ½°. R. 262°+38°.	105
1886	Oct. 2	8 57	4	266 +39	Sta. slow.	106
1886	May 5	14 35	2	266 +63	R. flash.	107

Stationary Meteors recorded at Bristol—continued.

Year.	Date.	G.M.T. h m	Mag.	Radiant. ° °	Notes.	Ref. No.
1903	Apr. 19	14 6	5	268 +33	Swift, streak. Lyrid.	108
1887	June 21	11 35	2	270 +47	Motionless.	109
1914	June 25	10 39	2	270 +44	Slight motion. R. 269°+48°.	110
1911	July 1	11 45	3	270 +29	Sta.	111
1915	June 1	11 18	4	270 +48	Sta. =109, 110.	112
1913	Sept. 27	7 26	3	270 +29½	V. nearly sta. =111.	113
1916	June 1	11 33	4	271 +22	V. nearly sta.	114
1921	Aug. 8	14 29	4	276 +22	Path 1°. R. 274°+22°.	115
1889	July 26	11 13½	2	274 +71	Sta. like a star.	116
1919	Apr. 29	10 33	2	279 +59	280°+59½°. R. 279°+59°.	117
1886	July 13	10 48	1	282 −32	B. Motionless.	118
1886	Nov. 17	6 36	2	284 +43	Sta. slow.	119
1907	Aug. 15	9 23	2	288 +61	Nearly sta.	120
1904	July 12	10 34	2	291 +12	Almost sta.	121
1903	May 18	11 45	4	291 +60	Almost sta. R. 290°+60°.	122
1911	July 23	11 2	2	292 +64	Motionless flash. =120, 122, 127.	123
1887	Jan. 25	13 43	4	291 +52	Sta.	124
1887	Mar. 28	11 35	4	291 +52	Sta.	125
1887	Mar. 28	12 27	4	292 +50	Sta. =124, 125, 130.	126
1917	July 27	10 29	4	293 +59½	Sta.	127
1887	July 20	13 31	4	294 +78	Swift, sta.	128
1887	July 29	10 19	1	295 −19	Sta.	129
1915	June 3	11 18	2	295 +54	N. sta. R.	130
1889	Apr. 22	10 49	2	298 +71	Slight motion from $\psi-\chi$ Draconis.	131
1914	July 17	10 54	5	300 +24	Slight motion. R. 300°+23°.	132
1917	Aug. 27	11 10	2	301 +74	N. sta. W.	133
1908	July 28	10 28	3	302 +23	Sta. R.W. =132.	134
1903	July 1	11 30	4	306 +62½	Almost sta. R. 310°+62°.	135
1905	Aug. 5	10 28	>1	305 +78	N. sta. flash.	136
1913	Nov. 8	6 48	2	305 +62½	Slight motion. R. 310°+62°.	137
1901	Apr. 20	12 2	4	308 +57	Slight motion. R. 308°+61°.	138
1919	Aug. 2	9 37	2	310 +80	Sta. sl. W.	139
1914	May 21	11 5	2	311 +62½	Almost sta. v. swift. R. 311°+62°.	140
1914	July 14	11 37	4	312 +65	R.W. 312°+62°. =135, 137, 138, 140, 142.	141
1919	Aug. 14	9 10	3	312½+64	311°+65°. R.W. 315°+62°.	142
1904	July 18	10 55	3	314 +79	Sta. W. =136, 139.	143
1887	June 17	13 49	1	316 − 6	Sparkling. Sta.	144
1918	Aug. 30	10 3	3	316 − 9	N. sta. =144.	145

Stationary Meteors recorded at Bristol—continued.

Year.	Date.	G.M.T. h m	Mag.	Radiant. ☌ °	Notes.	Ref. No.
1917	May 2	14 54	2	316¾ +50	Path 1°. R. 315°+48°.	146
1902	July 6	12 17	3	317 +12	Slight motion. R. 319°+11°.	147
1918	June 2	11 53	3	317 +30	W. flash. Sta.	148
1887	Sept. 6	8 37	3	317½+ 2	Slow, n. sta. R. 317½°+3°.	149
1915	Sept. 29	8 58	3	318 +19	Sta. flash.	150
1887	June 18	11 59	4	318½+45	R.W. N. sta. R. 316°+48°. =146.	151
1887	July 16	13 1	2	319 +18	Sl. sta.	152
1920	June 13	10 50	2	319 +19	N. sta. v. slow. =150, 152.	153
1915	Aug. 13	10 40½	2	330½+ 7	1¼°. Almost sta.	154
1887	Mar. 28	12 56	4	331 +50	V. sl. sta.	155
1913	Aug. 24	11 14	2	331 +36	Sta.	156
1908	Aug. 3	10 43	4	331 +32	Sta.	157
1921	Sept. 27	10 5½	5½	332 +35	Path ½°. R. 332°+36°. =156, ? 157.	158
1923	Sept. 30	7 44	2½	332 +50	V. n. sta. R. 333°+49°.	159
1918	Oct. 4	7 38	4	333 +59	Slight motion. R. 331°+57°.	160
1918	Nov. 27	6 31	2	334 +74	N. sta. v. v. v. sl.	161
1917	July 15	10 44	2	335 +27	Sta.	162
1899	Aug. 14	11 16	5	335 +55½	Very short. R. 332°+57°. =160.	163
1888	Aug. 5	12 34	1	336 −11	Sta.	164
1887	July 29	14 17	2	336 −11	Sta. like a star.	165
1918	Aug. 10	11 48	1	336 −12	No motion. =164, 165, 170.	166
1918	Sept. 1	9 46	5	336 +34½	Path 1°. R. 333°+34°.	167
1908	Aug. 6	12 15	5	337 +45	Sta. v. R.	168
1917	May 1	14 45	2	342½+42	Sta.	169
1879	Aug. 9	10 42	>1	342 −16	341°−13° flash.	170
1902	Oct. 2	8 27	4	345 + 2½	Almost sta. R. 347°+3°.	171
1907	Oct. 12	9 10	2	346 + 3	N. sta. from 348°+2°=171.	172
1888	Aug. 6	12 9	1	346 −46	1° sl. K. 5 sec.=175.	173
1917	Sept. 19	9 21	2	346 −11	Slight motion, sl. R. 350°−10°.	174
1913	Sept. 9	11 39	2	348 +45	Sta. =173.	175
1900	Sept. 24	9 37	4	350 +38	Sta.	176
1916	July 29	10 36	3	350 +31	Flash. R. 350°+31°.	177
1914	Nov. 10	6 41	2	354 +42	Path 1°. R. 352°+39°. =176.	178
1915	Aug. 16	9 50	1	355 +72	Slight motion, slow. R. 352°+72°.	179

Explanation of Abbreviations.

Sta. = Stationary.
N. = Nearly.
R. = Radiant where it comes before a position in R.A. and Dec. Rapid in other places.
V. v. = Very.
K. = Streak.
W. = White.
Sl. = Slow.

Bristol:
1923 *October* 17.

Radiant Points of Shooting Stars observed at Bristol chiefly from 1912 *to* 1922 *inclusive.* By W. F. Denning.

This list is in continuation of previous ones published in the *Monthly Notices* for 1877, 1890, and 1912, which included about 1168 radiants.

The present list contains 314 radiants for the period 1912 to 1922, during which I observed about 6220 meteors, of which number I recorded the flights of 4008. It is believed that the great majority of the positions may be depended upon certainly within 2° of probable error. In some cases I have placed the abbreviation "acc" in order to distinguish a position which I regarded at the times of observation as very accurate. This is not intended to imply that all those radiants not so marked are to some extent uncertain or inexact; indeed many of them are entitled to the same degree of confidence as those which have the affix to which I have referred, but in all the latter cases radiation appeared to be so definite and precise as to merit a special note. In comparing the present results with those previously published, it will be seen that there is ample corroboration of a great proportion of the radiant points I deduced in previous years.

In fact, it seems assured on ample evidence, that nearly all existing meteoric showers are of annual occurrence, though variations in their visible strength occur from year to year. I have observed since 1912 a great majority of the same radiant positions as were determined by me in 1876 and 1877 (interval about forty years), (see *Monthly Notices R.A.S.*, **37**, 105–115, and **38**, 303–314).

With regard to the connection between the orbits of comets and meteors, I have found a number of possible accordances to which special attention has not been directed. In several cases the agreements seem to be really good, and it may be fairly surmised that the meteors seen belong to the individual comets to which they have been attributed, for in both date and position of radiation there is a very near approach to identity in the figures. In some cases, however, the comet's orbit does not run near enough to the earth's track to warrant the assumption that the meteor stream is veritably derived from the comet's material. Thus, in the case of the periodical comet 1881 V., the comet passed about 10 millions of miles from the earth, and its particles must have been widely spread in order to occasion the meteoric shower.

We do not, however, know the extent of space over which cometary material may be distributed, but it is certainly very considerable. In the instance of the comet alluded to, the meteor shower falls significantly near the date and radiant of the comet.

One of the most remarkable of showers witnessed in recent years occurred in 1916 June 28 (see *Monthly Notices*, **76**, 740), and it seems undoubtedly attached to Pons-Winnecke's Comet, although the radiant point shows a discordance with that calculated for the comet. The agreement, however, is sufficiently near to strongly support the inference of identity, and planetary perturbations may well have introduced disturbances of the extent and nature of those observed.

Lexell's Comet of 1770 appears to have a meteoric shower, or, at any rate, a display of large meteors has been witnessed from Sagittarius in the summer months, which suggests an alliance in place and date with the well-known comet mentioned.

With regard to the determination of radiant points generally, it seems to me that this cannot be safely effected unless, in ordinary cases, at least 5 meteors are accurately recorded from each position. In some instances, however, the circumstances may be special, and an experienced observer may safely obtain a radiant from 3 or 4 meteors, particularly when their flights are upwards from a radiant near the horizon.

The observer, however, must invariably consider in the most critical manner the visible details of every meteor seen, or he cannot possibly allot the objects to their correct radiants. This fact will be appreciated by everyone who makes a deep study of the practical requirements and difficulties. In this connection a letter which can safely guide him in his deductions, written by the late Professor A. S. Herschel, can be studied with advantage (see *Observatory*, 34, 291, 1911 August).

As a rule radiant points ought to be found to within 2° of probable error, but different observers exhibit a personal equation, which is often widely dissimilar. One person will show an average error between 5° and 10°, whereas one of the most efficient workers will have an error of only 1° or 2°, and sometimes less than that. The fact is, that in certain cases no amount of training or experience will ensure accuracy in results, because the natural aptitude and ability are wanting.

In cases where a single observation of a meteor is used the radiant point has to be assumed, and no matter how skilled the observer may be he cannot fix the place with absolute certainty. If he considers the direction of flight only he has got very little evidence on which to safely judge, and he must carefully regard all the visible details of an object. I need not go into particulars as to these, but content myself with saying that a very large number of false radiants have been published, owing to the fact that many of the essential features which ought necessarily to have been considered were left out of the question.

Directly I see a meteor and mark its path on a celestial globe, I estimate the place of its radiant point while all the aspects of its flight are fresh in the memory. I have been enabled to find the relative number of my successful and unsuccessful attempts to apply the radiant, having computed the real paths of about 1200 fireballs and shooting stars observed in England by myself and others during the last thirty-five years. The result is that for all meteors, including Perseids, Leonids, and others, the proportion of successes is 3 out of 4, while for the minor and less known systems the figures are rather greater than 3 out of 5. In the instance of an observer having little experience and small acquaintance with the more scanty streams, attempts to locate the radiant positions must necessarily be a work almost beyond attainment.

Some years ago the late Mr. Bryan Cookson made an investigation as to the relative accuracy of a number of observers in ascertaining radiant

points. His conclusion was that a thoroughly experienced person, who took into account all the features calculated to help him in his judgment, could be depended upon to get the radiant points to within three-quarters of a degree of probable error.

With regard to stationary radiation I have very little to add to what has been written in previous papers for purposes of investigation. I published in 1919 the details of four well-defined radiant points apparently of long duration, as follows:—

Mean Radiant.	No. of Radiants.	Name of Shower.	Reference.
* 40°·6 + 20°·4	39	ϵ Arietids	*Observatory*, **42**, 246.
48·2 + 44·1	62	$\alpha - \beta$ Perseids	*Observatory*, **42**, 278.
162·0 + 58·0	26	β Ursids Maj.	*B.A.A. Jour.*, **29**, 132.
314·2 + 47·6	35	α Cygnids	*B.A.A. Jour.*, **29**, 161.

It is gratifying to notice that several mathematicians, including Professor W. H. Pickering, Professor H. C. Plummer, and Rev. M. Davidson, have approached this part of the subject with perfectly open minds, and have endeavoured to explain stationary radiation in a satisfactory way.

They have accounted for it in part at least, and no doubt a comprehensive theory will be ultimately found.

I recently undertook the work of collecting all the Perseid observations available, but the task soon attained proportions far beyond what I had expected. An enormous number of records of this August shower have now accumulated, and may be found in scientific journals of the last hundred years. My investigation was not quite completed, but I went far enough to gather the information needed and to ascertain, at least approximately, the varying strength of the display from year to year.

The annual returns have been affected, however, by many different circumstances and conditions, so that the records are not fairly comparable in many instances.

I tabulated all the accounts of ancient and modern displays going back to A.D. 714 July, and found it difficult to adopt any long period that would accommodate them. The parent comet (1862 III.) pursued an orbit having a time of revolution computed as about 117 or 124 years, while bright and abundant meteoric returns indicated a much shorter period, though a cycle of 105 years satisfied some of the maxima in a very suggestive way. But no long intervals seemed tenable, and I ultimately had to adopt a sub-multiple of 105 years, namely 11·72 years, as the best. This accords with many of the observed dates in a very significant manner, as shown in the following comparative table:—

* See *Monthly Notices*, **82**, 309, for ample confirmation of the long duration of this shower.

Observed Return Year.	Computed Return Period 11·72 Years.	Periods in Interval.	Observed Return Year.	Computed Return Period 11·72 Years.	Periods in Interval.
714	714		1451	1452·34	18
784	784·32	6	1592	1592·98	12
811·810			1709	1710·18	10
820			1779	1780·52	6
824			1781		
830	831·20	4	1784		
833			1789		
841	842·92	1	1839	1839·12	5
865	866·34	2	1851	1850·84	1
924	924·94	5	1863	1862·56	1
925			1874	1874·28	1
926·927			1886	1886·00	1
933	936·66	1	1898	1897·72	1
1243	1241·38	26	1921	1921·16	2

I have not included fairly abundant returns observed by Foster in 1806 and 1811 and by Howard in 1813, as it is by no means certain that these (and possibly some others included in the list) were really of specially active character.

One of the richest returns ever observed was that of 1921 August 11 when one observer might count 250 meteors per hour.

If the comet of 1862 III. is the derivative source of the shower, it is certain that the meteors are distributed in well-defined groups along the orbit, and that these groups or condensations give rise to the rich displays at comparatively short intervals.

With regard to the displacements in certain radiants, I find this is certainly proved in the cases of the Lyrids and Geminids as well as in that of the Perseids. For the latter shower, I first obtained convincing evidence of motion in the radiant in 1877, and for the Lyrids and Geminids in 1885.

The following are ephemerides for the two last-mentioned showers for alternate nights, but I have never observed Lyrids over so long an interval:—

Radiant of Lyrids.		Radiant of Geminids.	
Apr. 10	259°+34°	Nov. 25	91°+34°
12	262+34	27	93+34
14	264+33	29	96+34
16	266+33	Dec. 1	98+34
18	269+33	3	101+33
20	271+33	5	104+33
22	274+33	7	106+33
24	276+33	9	109+33
26	278+33	11	111+32
28	281+34	13	114+32
30	284+34	15	116+32
° south of Vega on Apr. 26.		At Castor on Dec. 12.	

I have seen Lyrids between April 14 and 26 and Geminids during the whole interval covered by the ephemeris. Observations of the Lyrids before April 15 and after April 25 will be valuable, but the display is a brief one, and two or three nights from the maximum (April 21) the meteors are very rare, and it is essential that special efforts should be made to procure multiple observations at two stations of early or late Lyrids. Single records of paths cannot always indicate the radiant with certainty.

In regard to the radiant of Quadrantids of January 3, Aquarids of July, Orionids of October, and Leonids and Andromedids of November, I have not found certain evidences of displacement.

Ref. No.	Year.	Date.	Radiant Point.	No. of Meteors.	Notes.
			° °		
1	1918	Aug. 28, Sept. 2	0 − 2	8	Very slow, near 5 Ceti.
2	1919	Sept. 17	4 − 2	4	Very bright. =1.
3	1919	Sept. 19	4 +44	2	R.
4	1915	Oct. 13	13 + 6	6	V.S. Well defined. Acc. ε Piscids.
5	1917	Oct. 6, 14	13 + 5	6	V.S. ε Piscids.
6	1916	Oct. 28, Nov. 1	14 + 7	7	V.S. Acc. =4, 5, 6. ε Piscids.
7	1918	July 1–10	16 +30	4	R.K. Acc. β Andromedids =Comet Brooks 1898 X. Rad. 15°+29°, June 28.
8	1914	Sept. 20, 24	17 +31	7	R.W. Acc. β Andromedids.
9	1919	Sept. 17, 18	19 +57	6	Moderate. δ Cassiopeids.
10	1921	Oct. 4–5	18 +31	4	R. β Andromedids. =7, 8, 10, 11.
11	1877–1918	Oct. 31, Nov. 15	19 +30	7	S.B. ,,
12	1918	Aug. 29, Sept. 5	23 +45	5	R. γ Andromedids
13	1919	Sept. 17–29	23 +42	4	R.W. ,,
14	1914	June 23–28	24 +42	8	R.K. ,, Acc.
15	1917	July 19–22, Aug. 11	23 +43		
16	1919	Sept. 30, Oct. 16, 21	26 +70	5	S. near star 50 Cassiopeiæ, meteors small and short.
17	1913	Nov. 18–21	27 +42	9	V.S. Andromedids of Biela's comet.
18	1919	Sept. 30	28 +71	..	Suspected. =16.
19	1916	Oct. 20–25	28 + 4	4	R.
20	1918	July 30	29 +54	9	Perseids. Acc.
21	1914	July 30	30 +54	..	R.K. Perseids. Acc.
22	1917	Oct. 14, 21	32 +19	8	V. slow. Acc.
23	1919	Oct. 20–22	33 +19	7	V. slow. Acc. =22. α Arietids.
24	1918	Aug. 5	35 +56	15	Perseids.
25	1918	Aug. 2	36 +56	6	,,
26	1916	July 25, 29	36 +47	7	R.K. θ Perseids.
27	1919	Aug. 2	38 +55	18	R.K. Perseids.

Ref. No.	Year.	Date.	Radiant Point.	No. of Meteors.	Notes.
28	1918	Aug. 2, 14	39° +27°	6	R.K.
29	1919	Aug. 5	40 +55	18	R.K. Perseids.
30	1915	Aug. 10	40 +55	6	R.K. ,,
31	1919	Oct. 16–22	40 +21	4	Slow. =32, 33, 34, 37, 39, 44, 46, 48, 54. Rich shower. ε Arietids, max. October. Long enduring until January.
32	1917	Oct. 21–24	41 +20	13	Slow. Acc. ε Arietids.
33	1917	July 19–21	41 +20	4	R.K. ε Arietids. Acc.
34	1917	Nov. 10	41 +22	4	V. slow. ε Arietids.
35	1918	Aug. 8	41 +58	14	R.K. Perseids. Acc.
36	1918	Aug. 10	42 +58	31	R.K. ,,
37	1914	Nov. 13	42 +20	4	Slow. W. Acc. ε Arietids.
38	1921	Aug. 8	42 +56	14	R.K. Perseids. Acc.
39	1916	Oct. 28, Nov. 3	42 +21	8	V. slow. Acc. ε Arietids.
40	1908	Aug. 23, 28, 30	42 +38	5	R.K. β Perseids.
41	1913	Aug. 6	42 +57	12	R.K. Perseids.
42	1919	Oct. 16–22	42 + 6	5	V. slow. α Cetids.
43	1920	Aug. 10	43 +58	12	R.K. Perseids.
44	1922	Oct. 23	43 +21	7	Slow, small. ε Arietids.
45	1908, etc.	June 25, 28	43 +37	4	R.K. Acc. β Perseids. =40.
46	1921	Nov. 4	43 +20	6	Slow. Acc. ε Arietids.
47	1914	Aug. 10	43 +56	15	R.K. Perseids.
48	1921	Nov. 6	43 +19	8	Slow. ε Arietids.
49	1877–1918	Nov. 3–7	44 +59	8	Slowish. Acc.
50	1921	Aug. 11	44 +57½	122	R.K. Acc. Perseids. A fine display this year. 250 horary rate on morning of Aug. 12.
51	1917	Oct. 18–24	44 + 9	7	V. slow.
52	1913	Oct. 26–28	44 + 5	10	Slow. =42, 51, 53, 58. α Cetids.
53	1920	Nov. 11–12	45 + 5	..	Slow. B. Suspected. ,,
54	1921	Oct. 27–29	44 +21	10	Slow. Acc. α Arietids.
55	1919	Aug. 12	45 +57	19	R.K. Perseids.
56	1917	Aug. 11	45 +58	195	R.K. Perseids. Acc.
57	1912	Aug. 11	45 +58	12	R.K. ,,
58	1877–1918	Nov. 3–5	46 + 5	10	V. slow. α Cetids.
59	1920	Sept. 18	46 +42	5	R.W. α–β Perseids.
60	1919	Oct. 16–22	47 +43	6	R. ,,
61	1918	Aug. 28, Sept. 6	47 +43	4	R.K. ,, Acc.
62	1916–17	Oct. 26–Nov. 3	47 +43	5	Slow. ,, ,,
63	1914	Aug. 11	47 +56	32	R.K. Perseids.

Ref. No.	Year.	Date.	Radiant Point.	No. of Meteors.	Notes.
64	1915	Aug. 12	47° +58°	68	R.K. Perseids. Acc.
65	1919	July 30, Aug. 12	48 +44	12	R.K. Acc. $\alpha-\beta$ Perseids.
66	1913	Aug. 13	48 +57	6	R.K. Perseids.
67	1876–1915	Apr. 12, 23	48 +43	7	V. slow. Acc. $\alpha-\beta$ Perseids.
68	1877–1914	Nov. 2–5	48 +43	16	V. slow. Acc. $\alpha-\beta$ Perseids.
		Nov. 10–22		15	,, Places redetermined.
		Nov. 27, Dec. 2		6	,, V. acc.
69	1915–17	Dec. 14, 21	49 +45	6	$\alpha-\beta$ Perseids. =59, 60, 61, 62, 65, 67, 68. A strong shower, often recurrent July to Dec.
70	1918	Aug. 12	49 +58	96	Perseids.
71	Various.	Oct. 25, Nov. 8	49 −13	5	V. Slow. Southern showers; others seen at 2°−16° and 34°−27°, October.
72	1915	Aug. 13	49 +58	29	R.K. Perseids.
73	1918	Aug. 13	50 +59	10	Perseids.
74	1918	Aug. 14	50 +59	22	,, Acc.
75	1922	Aug. 15	51 +58	5	,, ,,
76	1919	Oct. 18, 22	54 +71	4	Slow. Acc. γ Camelopardalids.
77	1914	Aug. 16	56 +59	8	R.K. Perseids. Acc.
78	1886	Nov. 2–3	60 +34	4	R. ε Perseids. A well-defined and fairly rich shower. Max. about Sept. 6–15 and Nov. 3–6. Discovered in 1877.
79	1880–1901	Aug. 10, 11	60 +35	8	R.K. ε Perseids. Acc.
80	1916	Nov. 1–3	60 +34	7	R. ,, ,,
81	1910–14	Nov. 9, 10	61 +35	6	R. ,, ,,
82	1877–85	Nov. 10–17	61 +33	10	V. slow. =78, 79, 80, 81.
83	1917, etc.	Oct. 23, Nov. 4	61 −11	6	Slow. Acc. γ Eridanids.
84	1916	Nov. 1	64 +22	2	Suspected. Acc. Taurids.
85	1913	Aug. 20, 28	64 +60	5	R.K. ? Perseids.
86	1913	Oct. 23, 28	64 +22	5	Slow. Taurids
87	1888–1921	Oct. 28–30	65 +23	6	V.S. Acc. ,,
88	1913	Nov. 21	64 +22	7	V.S. ,, ,,
					A rich shower in Oct. and Nov., but there are meteors from same radiant in Aug. and Sept. also.
89	1921	Oct. 8	65 +22	6	Slowish. Acc. Taurids. =84, 86, 88. Gives many brilliant meteors in Nov.
	1888–1921	Oct. 28–30		6	
90	1919	Aug. 9–22	70 +66	5	R.K. Acc. α Camelopardalids.
91	1919	Sept. 16, 29	71 +61	6	R.K. Distinct to following.
92	1916	Oct. 20–25	72 +66	6	Slow. Acc. α Camelopardalids. =90.

Ref. No.	Year.	Date.	Radiant Point.	No. of Meteors.	Notes.
			° °		
93	1916	Oct. 25	73 +41	4	Suspected. α Aurigids.
94	1917	Nov. 10–14	74 +43	5	Slowish. ,, =93.
95	Various.	Oct. 17–21	77 −12	5	R. 4° S. of Rigel. Acc.
96	1920–21	Sept. 18–25	79 +23	5	R.K. Acc. Early. ζ Taurids.
97	Various.	Oct. 17–21	83 −21	4	R.
97*a*			84 − 5	5	R. Suspected.
98	1876–1915	Sept. 4	88 +54	6	R.K. Perseids.
99	1922	Oct. 23	91 +16	5	R.K. Orionids.
100	1886	Dec. 14–25	90 +15	4	Slow. Acc. Very definite radiant from same point as Orionids.
101	Various.	Oct. 3–12	91¼+14½	10	R.K. Orionids. This shower of swift, streaking meteors appears to continue actively from Oct. 11–27.
102	1914	Oct. 25	91½+14	4	R.K. Orionids. Acc.
103	1916	Oct. 20	92 +15	6	R.K. ,, ,,
104	1917	Oct. 16, 24	92 +15	24	R.K. ,, ,,
105	1913	Oct. 21–28	92 +16	6	R.K. ,,
106	1913	Oct. 16	91 +15½	4	R.K. ,,
107	1913	Oct. 17	91 +16	7	R.K. ,, Acc.
108	1913	Oct. 18	91 +15	..	Suspected. Orionids.
109	1913	Oct. 21	92 +15	7	R.K. ,,
110	1919	Oct. 18–22	92 +20	6	R.K. Acc. Sharply defined and quite distinct to the Orionids. =113.
111	1919	Oct. 18	92¼+14½	12	R.K. Acc.
112	Various.	Oct. 25, Nov. 7	92½+14	18	R.K. Orionids.
113	1917	Oct. 26	92 +21½	4	R.K. Acc. =110. η Geminids.
114	1916	Oct. 22	96½+13½	8	R.K. ,,
115	1917	Oct. 16–24	98 +14	30	R.K. Acc. } Rich shower of Geminids contemporary with Orionids.
116	1916	Oct. 23	98 +14	4	R.K. ,, }
117	Various.	Oct. 16, 24	99 −16	4	R.K. Near Sirius. Acc.
118	1919	Oct. 18–26	100 +13	5	R.K.
119	1919	Aug. 22–27	103 +34	5	R.K. Acc. θ Geminids.
120	1916	Dec. 4	104 +32	4	R.G. Early. α Geminids.
121	1916	Oct. 20, 31	104 +77	4	R.
122	1921	Dec. 28–29	102 +34	6	Slow. Acc. First seen at Bristol 1872 Dec. 31. A good shower.
123	1917	Oct. 18	104 +34	4	R. Acc. =119, 122.
124	1914	Dec. 8	105 +31	4	R.K. α Geminids.
125	1914	Sept. 21–27	106 +51	6	V.R. Acc. Lyneids.

Ref. No.	Year.	Date.	Radiant Point.	No. of Meteors.	Notes.
			° °		
126	1919	Dec. 13	107 +24	12	R.R. Yell. Acc. δ Geminids.
127	Various.	Oct. 15, Nov. 14	108 −23	6	R.K. Acc. o Canis Minorids.
128	1921	Dec. 9	108 +32½	8	R.W. Acc. α Geminids.
129	1914	Dec. 12	109 +33	6	R.G. „ „
130	1915	Dec. 12	110 +33	12	R.W. „ „
131	1914–17	Mar. 18–22	110 +53	6	Sl. B. =125. In Jan. and at other times also.
132	1917	Dec. 12	112 +33	12	R.W. Max. Dec. 12. Geminids. Radiant advances with the time.
133	1919	Dec. 13	114 +33½	18	Slowish. W. α Geminids.
134	1914	Dec. 15	114 +33	6	R.W. α Geminids. =120, 124, 128, 129, 130, 132, 133.
135	1915	Dec. 12	118 +32	6	R.
136	1920	Nov. 10, 12	120 ± 0	4	R.K. Suspected.
137	1919	Oct. 26	120 +31	4	R.K.
138	1916	Oct. 25, Nov. 1	121 +43	7	R.K. Acc.
139	1916–17	Oct. 21, Nov. 3	122 +19	4	R.K. δ Cancrids.
140	1916	Dec. 4	126 +44	4	R. =138.
141	1921	Jan. 10	130 + 9	4	Slow.
142	1916–17	Oct. 16–26, Nov. 3	133 +31	6	R.K. Well defined. ι Cancrids.
143	1877–1917	Feb. 15–21	134 +76	7	V. slow.
144	1917	Dec. 18, 21	134 +68	4	V. slow.
145	1921	Sept. 25–28	135 +59	5	R.K. V. acc.
146	1919	Oct. 22–27	141 +37	5	R.K. Acc. Well defined.
147	Various.	Oct. 16, Nov. 12	146 + 6	6	R.K.
148	1917	Nov. 10	150 +22	4	R.K. Leonids.
149	1917	Mar. 18–23	150 +40	4	V. slow
150	1917	Oct. 18–23	154 +42	6	R.K. μ Ursæ Majorids. =Comet 1739. A fine shower.
151	1906–17	Apr. 7–15	152 +39	6	V. slow
152	1877–87	Oct. 15–16	153 +41	7	R.K. Acc. μ Ursæ Majorids.
153	1885	Nov. 17	153 +32	4	R.K.
154	1876–77	Dec. 10–13	155 +40	8	R.K. =149, 150, 151, 152. Acc. μ Ursæ Majorids.
155	1916	Oct. 20–25	160 +72	6	Rapid. Acc. =160, 163. λ Draconids.
156	1877–1909	Feb. 20–26	161 +59	6	Rapid. Acc. β Ursæ Majorids.
157	1915	Apr. 14–18	161 +58	4	Slow. „ „
158	1920	Dec. 18–21	162 +58	16	Slowish. Acc. Max. Dec. 21. β Ursæ Majorids.
159	1917	Oct. 13–18	163 +59	10	R. Acc. =156, 157, 158. β Majorids.

Ref. No.	Year.	Date	Radiant Point.	No. of Meteors.	Notes.
160	1916	Nov. 27	164° +72°	..	Suspected. =155, ?163.
161	1916	Apr. 26–30	171 +20	5	Slowish.
162	1876–1913	Apr. 14–27	173 −19	4	V. slow.
163	1919	Sept. 29	174 +71	2	Slowish. Suspected.
164	1876–1913	Apr. 14–27	176 −30	4	V. slow.
165	1876–1913	Apr. 14–27	189 −18	10	V. slow.
166	1917	Dec. 2–9	190 +68	8	Rapid.
167	1876–1913	Apr. 14–27	190 −31	..	V. slow.
168	1917	Nov. 7–10	192 +76	3	Suspected.
169	Various.	Dec. 18–22	192 +69	10	=166, 170. Acc.
170	1912	Apr. 10–14	197 +71	4	Slow.
171	1913	Apr. 12–22	200 + 8	4	Slow. Acc.
172	1912	Apr. 19–23	201 + 8	6	V. slow. =171. Acc.
173	1909–14	Apr. 20–27	204 +56	6	ζ Ursæ Majorids.
174	1915	Apr. 12–15	209 −10	4	Slow. Acc. Rich shower. Meteors with long paths and trains.
175	1917	Dec. 18–21	214 +52	2	Suspected. Many radiants here on other dates of the year.
176	1917	Dec. 18–21	216 +66	6	Acc.
177	Various.	Dec. 18–22	218 +76	7	Acc. =Mechain-Tuttle's Comet.
178	1920	Mar. 11–12	218 +12	4	V. slow. Acc. ζ Boötids. Apparently this radiant is continuous or subject to repetitions between Dec. and Aug. 25.
179	1915	Apr. 12–18	219 +13	5	V. slow. Acc. ζ Boötids.
180	1912	Apr. 16–22	219 +78	5	V. slow. =177.
181	1877–1915	Apr. 12, 26	220 +13	15	Slow. =178, 179, 181. Acc. ζ Boötids.
182	1887–1905	Mar. 27, 30	220 +40	4	Swift. β Boötids.
183	1916	June 28	221 +56	65	Apparently very diffuse radiation from Pons-Winnecke's Comet.
184	1916	June 28	231 +54		
185*a*	1916	June 28	213 +53		
185	1916	June 28	223 +41		
186	1921	June 28	228 +58	7	Slow. B. Acc.
187	1918	May 18, June 10	228 − 7	5	V. slow. Acc.
188	1919	May 19, 28	229 +34	5	V. slow. θ Coronids.
189	1918	June 3–7	230 +34	4	V. slow. Acc. θ Coronids.
190	1917	Dec. 18–21	230 +33	4	V.R. ,, ,,
191	1921	Jan. 2	231 +54	19	Slowish. Quadrantids.
192	1922	Jan. 3	231 +53	30	Sl. and v. slow. Max. in 1918 and 1922.

Ref. No.	Year.	Date.	Radiant Point.	No. of Meteors.	Notes.
1193	1891	Mar. 27, 30	231° +50°	7	Slow. Quadrantids.
1194	1919	Jan. 1–3	232 +50	6	Swift. ,,
1195	1916	Oct. 25, Nov. 5	232 +68	8	Acc. Very sharply defined.
1196	1913	Jan. 2.	232 +51	4	Quadrantids.
1197	1916	Jan. 3	232 +52	4	,,
1198	1919	Jan. 1–3	233 +61	5	Slow.
1199	1918	Jan. 3	234 +59½	11	V. slow. Acc. R. 6° N. of normal place.
1200	1918	Apr. 19, 20	237 +19½	5	Slow. V. acc.
1201	1918	Aug. 28, Sept. 1	242 +49	4	Slow. Acc.
1202	1917	Apr. 14–20	243 +49	5	Rapid. ,,
1203	1921	June 28, July 5	243 +64	6	Slow. B. Acc. η Draconids.
1204	1913	June 1	245 +32	4	Slowish.
1205	1914	Mar. 24, Apr. 12	247 +34	4	Rapid. =204.
1206	1918	May 29–June 3	252 +53	8	Rapid.
1207	1886–1912	June 2–4	252 −10	10	V. slow.
1208	1919	July 23, Aug. 2	259 +38	6	Slow. Herculids.
1209	1919	May 19–28	259 − 4	5	Slow.
1210	1903–11	June and Sept.	262 −12	6	Slow.
1211	1918	Aug. 28, Sept. 2	265 +63	7	Slow, bright.
1212	1920	Apr. 19	269 +30	4	R.K. Lyrids.
1213	1915	June 1–3	269 +49	4	R.W. Rich shower of γ Draconids. Visible Mar. to Oct.
1214	1920	Apr. 19, 20–21	270 +31	6	R.K. Lyrids.
1215	1914	Sept. 23–24	270 +50	4	R.W. γ Draconids.
1216	1888–1910	Oct. 4, 17	270 +46	6	Slow. ,,
1217	1912	Apr. 16–22	270 +32	6	Slow. W.K. Lyrids.
1218	1877–1913	Mar. 8, 17	270 +48	5	R.K. Acc. γ Draconids.
1219	1915	May 24, June 3	270 +49	4	Slowish. =213, 215, 216, 218.
1220	1917	Sept. 9–21	271 +22	4	Slow.
1221	1919	Apr. 21	272 +30	9	R.K. Lyrids. Rad. advances 1° diurnally.
1222	1878–1917	Sept. 19–27	272 +23	21	V. slow. Active radiant.
1223	1903	May 23, June 1	272 +22	6	Rapid. =220, 221, 222, 224.
1224	1920	June 13	274 +22	4	Not v. swift.
1225	1919	July 20, Aug. 16	280 +57	5	V. slow.
1226	1914	Aug. 12–21	280 +44	20	R.W. Rich shower. Bright, white flashing meteors. Acc.
1227	1914	May 31, June 15	280 −12	4	R. λ Aquilids.
1228	1919	July 20, Aug. 2	281 +36 292 +35	6	Slowish. Apparently double.

Ref. No.	Year.	Date.	Radiant Point.	No. of Meteors.	Notes.
			° °		
229	1914	June 10, July 13	282 −13	6	Slow.
230	1887–1917	June 8–29	282 −26	10	V. exact. ?=Lexell's Comet of 1770.
231	1919	Aug. 2, 6	284 −21	4	V. slow. =230.
232	1912	June 29, July 12	285 −12	4	V. slow. =227, 229, 231. λ Aquilids. Rich shower from May to Aug.
233	1918	Aug. 13, 14	290 +52	4	R. θ Cygnids. Rad. often recurrent.
234	1919	Sept. 16–29	290 +52	12	R.W. Bright, flashing meteors. Acc.
235	1920	Sept. 12	290 +67	4	Swift.
236	1920	Oct. 6–9	290 +68	6	Slow. =235.
237	1877–1918	Sept. 4–8	291 +29	7	B. V. slow. β Cygnids.
238	1917	Aug. 11	292 +50	6	Slow. B.W. Acc.
239	1914	Aug. 21, 30	292 +51	8	R. Blue. W. Small. Acc.
240	1922	Aug. 25	293 +51	5	R. =233, 234, 238, 239.
241	1920	Aug. 20–22	297 + 0	3	R. V. slow.
242	1919	June 21, 28	302 −11	4	Slow. T. Rad. rich in July and Aug. B. long-pathed meteors. α Capricornids.
243	1917	Dec. 1–9	302 +24	9	Very slow. Red.
244	1918	Aug. 2, 8	302 − 9	6	Slow. =Comet V. 1881. Radiant Aug. 4. 303°−10°. α Capricornids.
245	1914	July 11–12	302 +23	4	Slowish. Rad. rich and long enduring. Visible between Apr. and Dec.
246	1908–11	Sept. 1–3	302 +22	14	Slow. Acc. Sagittids.
247	1913	July 25, Aug. 1	302 +23	4	V. slow. ,, ,,
248	1916	July 7, Aug. 7	302 − 8	20	V. slow. Bright. Acc. α Capricornids. Max. in 1916 July 25.
249	1916	July 25–31	302 +24	5	Rapid. Acc. Sagittids.
250	1919	July 20, Aug. 5	303 − 9	6	Slow. T.B. Acc. α Capricornids. =242, 244, 248, 254.
251	1919	Aug. 2–6	303 +24	5	Rapid. Sagittids.
252	1915	Sept. 10–11	303 +24	4	,, ,,
253	1911	Sept. 20, Oct. 3	304 +23	6	Slow. =243, 245, 246, 247, 249, 251, 252.
254	1913	Aug. 1–8	304 −11	4	Slow. Rad. recurrent till Oct.
255	1914	Aug. 26–27	309 + 6	5	Slow. B. Acc.
256	1920	Oct. 9	310 +80	4	Suspected. Acc.
257	1919	Aug. 2, 6	310 +80	8	Slow. κ Cepheids.
258	1915	Sept. 11–19	310 +78	4	V.R.

Ref. No.	Year.	Date.	Radiant Point.	No. of Meteors.	Notes.
			° °		
259	1901	Aug. 4, 21	311 +62	7	Acc. α Cepheids.
260	1877–1918	Oct. 29, Nov. 5	312 +47	8	Slow. α Cygnids.
261	1919	Sept. 15–29	312 +79	5	Slow. =256, 257, 258, 272. Obs. max. 1877 Oct. 3–4.
262	1915	Sept. 4–10	312 +62	4	Rapid. Acc.
263	1901–14	Apr. 14, 22	312 +61	8	R. Acc. α Cepheids. Well defined and long enduring. ?=Comet 1850 I. June 23. 313°+60°.
264	1901–14	July 27, Aug. 6	312 +62	4	
265	1901–14	Sept. 23–27	312 +61	4	
266	1919	July 30, Aug. 2	313 +48	5	Slow. α Cygnids.
267	1916	Nov. 1–3	314 +61	3	Slow. α Cepheids.
268	1916–17	Oct. 20, Nov. 3	314 +61	6	Slowish. ,,
269	1918	Aug. 28, Sept. 2	314 +61	5	R.W. =259, 262, 263, 264, 265, 267, 268.
270	1916	July 25, Aug. 2	314 +46	6	R. Short. α Cygnids.
271	1877–1918	Sept. 3–6	315 +48	6	α Cygnids. =260, 266, 270, 274, 275, 276, 277, 278. Well defined and long enduring.
272	1917	Oct. 23	315 +79	3	Slowish.
273	1917	July 19–22	315 +14	4	Slow.
274	1917	Aug. 15–23	315 +47	4	R. α Cygnids.
275	1917	July 19–22	316 +48	6	Acc. ,,
276	1919	Sept. 13–29	316 +46	5	Slowish. ,,
277	1877–1918	Sept. 14–23	316 +47	6	Acc. ,,
278	1918	Sept. 12	318 +48	7	Slow. ,,
279	1916	July 29, Aug. 2	320 −20	4	R.W.
280	1920	June	320 +19	3	R.K.
281	1887	June 21–25	321 −22	..	Suspected.
282	1888–1902	July 13–24	322 −23	4	Acc.
283	1908	Aug. 17–19	324 −20	5	Slow.
284	1900	Sept. 1–5	323 −24	4	=279, 281, 282, 283.
285	1919	Sept. 23–29	325 +63	6	W. Slow. Acc.
286	1918	Aug. 28, Sept. 6	326 +78	6	R.
287	1921	Oct. 4–5	333 +73	5	R. Acc. β Cepheids.
288	1918	Aug. 28, Sept. 2	332 + 5	6	Slow. Small.
289	1919	Aug. 20–27	332 +57	6	Slow. Acc. ζ Cepheids.
290	1914	Aug. 20–24	332 +36	4	V. slow.
291	1914	July 22–27	332 +39	6	R.W.
292	1916	July 19, Aug. 1	332 +37	4	R. =290, 291. π Pegasids.
293	1918	Aug. 28, Sept. 6	332 +57	8	Slow. Acc. ζ Cepheids.
294	1919	Sept. 17–18	333 +73	4	Slowish. Acc. β Cepheids. =287.

Ref. No.	Year.	Date.	Radiant Point.	No. of Meteors.	Notes.
295	1916	July 23–29	333° +58°	7	R. Acc. ζ Cepheids.
296	1918	Aug. 5–12	334 +57	5	Slowish. Acc. =289, 293, 295, 296. ζ Cepheids.
297	1913	June 23–28	334 +48	4	R. slow. Lacertids.
298	1918	Aug. 5–14	336 + 4	6	Slow. =288.
299	1919	Aug. 3–6	336 −10	9	V. swift. δ Aquarids. Max. July 27–31. Recurrent until Dec. 15.
300	1918	Aug. 28, Sept. 2	337 −11	6	Slow. Acc.
301	1918–21	Sept. 2–7	338 −12	6	Slow. Acc. δ Aquarids.
302	1916	July 23–31	338 −11	10	Slow. W. Acc. „
303	1877–89	Aug. 6–12	338 − 9	14	Slow. =299, 300, 301, 302. δ Aquarids.
304	1917 Oct. 19–21 1917 Sept. 20 1902 July 15 1916 July 23		344 +13	8	Very slow. Acc. Swift in July. =Comet 1770 II. or 1822 III.
305	1921	July 7–11	343 +11½	7	R.K. Acc. =304.
306	1919	Aug. 21–22	345 − 0	6	Slow. Acc.
307	1919	Aug. 20–22	348 +61	6	Slow.
308	1918	Aug. 28, Sept. 2	352 +76	7	R.W. γ Cepheids.
309	1921	Oct. 4–5	352 +51½	6	Slow. Acc.
310	1914	Sept. 27	352 + 2	4	Slow.
311	1919	July 30, Aug. 7	352 + 5	5	R. =310.
312	1914	June 25	354 +77	2	Suspected. =γ Cepheids.
313	1919	Sept. 29, Oct. 2	355 +40	5	Slowish. W. Acc.
314	1914	Various. Aug. 16–30	355 +77	11	Acc. γ Cepheids. =308, 312.

Explanation of Abbreviations.

Acc. = Accurate.
R. = Rapid.
S. = Slow.
F. = Faint.
B. = Bright.
K. = Streak.
V. = Very.

Bristol:
1923 *October* 17.

Note on Recent Occultations of α Tauri. By Rev. T. E. R. Phillips.

Occultations of this star were observed at Headley on (1) 1922 Nov. 6, (2) 1923 Jan. 27, and (3) 1923 Oct. 27, as follows:—

(1) The disappearance was observed with the 12¼-inch Calver Equatorial Reflector and power 296. The time was not taken, but it may be worth while to record that the star at disappearance seemed to glide completely in front of the Moon's limb and then suddenly vanished.

(2) Despite passing clouds both the disappearance and reappearance were observed under fairly good conditions. The instrument used at both phases was the 8-inch refractor. At disappearance (dark limb) the eyepiece employed gave a magnification of 700, and the star disappeared, if not absolutely instantaneously, at any rate after a very small fraction of a second. There was thin cloud at the time of reappearance and the Moon was low. The power used was 150.

(3) There were drifting clouds at times and the seeing was bad, but both the disappearance and reappearance were observed. I again used the 8-inch refractor. Mr. R. L. Waterfield was present and observed with the 18-inch reflector. At disappearance (bright limb) the star seemed to me to enter a small indentation in the limb, and I thought its light showed a perceptible diminution just before it vanished, but there was no appearance of projection in front of the Moon's limb as on 1922 Nov. 6, though I was rather expecting such an effect. The power used was 387. Mr. Waterfield at the 18-inch reflector, using a power of about 150, had a very distinct impression of projection. There was nothing remarkable about the reappearance.

The following are the observed times and other particulars of the occultations:—

Date.	Phase.	Angle from N. Point (Greenwich).	Moon's Limb.	Observed G.M.T. h m s	Observer.
1923 Jan. 27	Dis.	56°	Dark	12 35 45·8	P.
,,	Reap.	298°	Bright	13 30 43·8	P.
Oct. 27	Dis.	15°	Bright	11 15 43·0	P.
,,	Reap.	314°	Dark	11 54 35·3	P.
,,	Reap.	314°	Dark	11 54 36·6	W.

In the last column P = Phillips, W = Waterfield.
The position of the observatory is:—

Long. 0° 16′ 2″·2 W. Lat. 51° 16′ 32″·2 N.

Headley, Epsom.

Observation of the Occultation of α Tauri on 1923 *October* 27, *made at Gorse Cliff School, Boscombe, Hants.* By B. M. Peek, M.A.

Longitude, 1° 50′ 41″·7 W.\
Latitude, 50° 43′ 22″·4 N. / From 6-inch Ordnance Survey, 1910 edition.

Instrument, 12¼-inch reflector.

Times { Disappearance 11h 13m 27s·7.
Reappearance 11h 51m 50s·2.

The above times, which were obtained at the instrument by a stop-watch registering tenths of a second, have been corrected by 0s·7 and 0s·8 respectively for personal equation. The personal equation of the observer for disappearances under normal conditions has been determined by experiment at 0s·5 lag in starting the watch; an extra 0s·2 has been allowed as the disappearance took place at the bright limb, while the correction for the reappearance has only been inferred. The clock, which was keeping a steady rate, was checked at 10h 45m by the FL time signals.

Clouds were driving across the sky, which was mainly overcast, and it was very fortunate that both phenomena were observed through gaps. At disappearance the star and moon were somewhat dimmed by cloud, but nevertheless the star appeared slightly projected within the moon's limb. Disappearance was instantaneous. The reappearance did not seem to be absolutely sudden, but at any rate occupied a fraction of a second too small to estimate—possibly one-fifth, possibly one-tenth, possibly less.

Erratum.

M.N., 83, 418, footnote, *for* 2×10^6 *read* 2×10^9.